# Summary of approaches to account for and monitor indirect impacts of biofuel production

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*-Confidential-*

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# Foreword

Ecofys would like to thank all those that have contributed to this study. In addition we would like to thank the authors of the studies we have reviewed that have participated in very useful discussions on their work. These are representatives of EPA, CARB, LEI and the European Commission and Tim Searchinger on a personal note.

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Ecofys

# Summary

Indirect impacts of biofuel production have received increasing attention over the past years. These indirect impacts are impacts of biofuel production that occur as a result of market mechanisms. The two main negative indirect impacts are indirect land use change and competition with food. These impacts can lead to negative effects on greenhouse gas emissions, biodiversity and food consumption and are difficult to quantify because they occur through diffuse market mechanisms.

From a review of seven (scientific) initiatives that aim to quantify these indirect impacts it becomes clear that:

- No information is available on the magnitude of indirect impacts on biodiversity.
- Limited information is available on the magnitude of indirect impacts on food consumption.
- Indirect impacts on the greenhouse gas balance of biofuels through land use changes are predicted to be between 30 and 103 gCO2eq/MJ biofuel.

The large range of estimates of indirect impacts on the greenhouse gas balance of biofuels is found to be mainly caused by different values for the following key input assumptions used by the quantification initiatives:

- The choice of feedstock for the additional biofuel demand.
- The relationship between agricultural intensification and commodity prices and/or demand.
- The relationships between commodity demand, commodity prices and food demand.
- Assumptions on types of land use change caused by cropland expansion.
- Assumptions on carbon stocks of land types affected by cropland expansion.

From a review of five mitigation initiatives for indirect impacts it is found that mitigation measures are still in a development stage. In addition, they do not always include incentives for individual biofuel stakeholders to pursue strategies that minimise or eliminate the risks of indirect impacts. Nonetheless, initiatives are underway that aim to provide practical solutions for biofuel (feedstock) producers to minimise the risk of unwanted indirect effects of biofuel production.

From a review of two monitoring initiatives of indirect impacts it can be shown that monitoring of direct and indirect impacts hardly takes place today. Key challenges for monitoring of indirect impacts of biofuel production include: a) a lack of data on the impacts of agriculture in general, e.g. on deforestation, and b) the challenge to link measurable impacts such as deforestation to biofuel production as these impacts occur through market mechanisms that can not be directly measured. The data availability may improve when companies need to demonstrate the sustainability of their biofuels under the EU Renewable Energy Directive. The fact that indirect impacts occur through diffuse market mechanisms implies that the monitoring of such indirect impacts will always require a certain amount of modelling.

From the reviews on quantification, mitigation and monitoring initiatives, combined with experience on indirect impacts, Ecofys gives three main recommendations to the Ministry of VROM on what approach to take on indirect impacts:

- Focus policy on mitigation options, both on long term global solutions that go beyond biofuels, and on short term project level solutions specifically targeted at biofuels.
- Do not perform own modelling of indirect effects, but support more research on key model assumptions, such as yield developments or the dynamics of biofuel co-products in feed markets.
- Support structural monitoring of the impacts of agriculture in general, and support additional work to understand what measurable indicators provide a better insight in the role of biofuel production in the total impacts (from agriculture).

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# 1 Introduction

*This chapter introduces the concept of indirect impacts of biofuel production then discusses the difficulties in assessing indirect impacts. Finally, the aim and structure of this study are outlined.*

## 1.1 Indirect impacts of biofuel production

Sustainability is an important aspect of current biofuel production and use. At the start of the strong growth of biofuel production and use in the last decade, most attention was given to the direct impacts of biofuel production. These include for example: land use change[1] effects when starting a biofuel crop plantation; fertilizer, water and fuel use during feedstock production; fuel and chemical use during the processing of feedstock to fuel; and fuel use during the distribution of the fuel. The focus in studying these direct impacts is on their effect on the overall greenhouse gas (GHG) balance of the biofuel. In addition, the direct impacts of biofuel production on environmental aspects such as biodiversity, water, air and soil have been assessed, as well as the direct impacts on social aspects such as land use rights and labour conditions.

In more recent years, increasing attention is given to the indirect impacts[2] of biofuel production which are impacts of biofuel production that are the result of market mechanisms. The two main negative indirect impacts are indirect land use change (ILUC) and competition with food. These indirect impacts have become one of the key challenges to large scale sustainable biofuel production from energy crops.

ILUC occurs when the production of biomass feedstock displaces activities to other areas where they cause land use change and thus have potentially negative impacts on aspects such as carbon stocks and biodiversity. An example of this is when demand for palm oil for the biofuel market is supplied from existing plantations that used to supply to the food market as in Illustration 1 - 1. As palm oil is now supplied to the energy sector, the food sector is confronted with a (temporary) shortage in supply. In the short run this will lead to higher prices as supply is slow to adapt to the new market circumstances. In time, the higher prices may lead to a production increase, which could require additional plantations, leading to land use change. The location of this indirect land use change is uncertain, and more importantly, is out of the control of the biofuel producer and consumer.

[1] Land use change means that the use of a certain area of land changes between different types. For example, a forest is cleared and taken into use as agricultural cropland, or currently unused grassland is turned into pasture for cattle grazing. Land use change can have an impact on the carbon stock (the amount of carbon stored in the vegetation and soil) and biodiversity of the land, which can be unwanted.
[2] Indirect impacts are sometimes also referred to as ‘indirect effects’, ‘displacement effects’, ‘indirect land use change’ or ‘macro effects’.

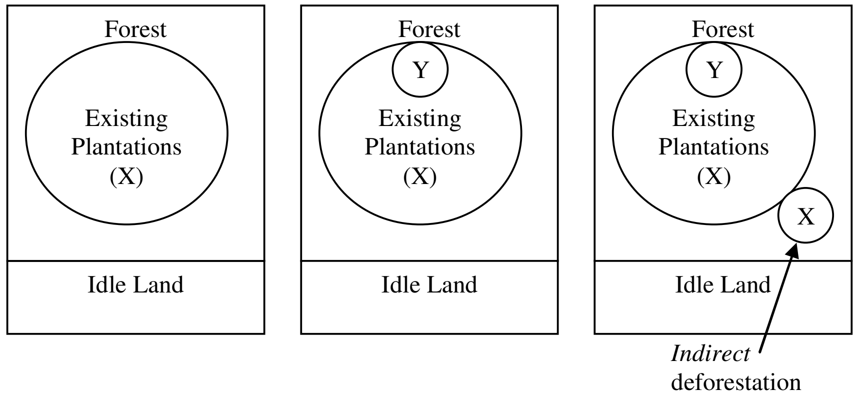


Illustration 1 - 1 Example of displacement mechanism causing indirect deforestation. Y is new demand from the bioenergy sector from existing plantations. X is expansion of existing plantations as a result of displacement effects. (Dehue, 2006)

The second main indirect impact of biofuel production, competition with food, starts with the same market mechanism as ILUC as described above: increasing demand for agricultural commodities for biofuel production leading to price increases. However, this time the increased demand in the biofuel sector is not met by increased production over time. Instead, there is reduced demand for the commodity in the food sector because not all consumers are able or willing to pay the increased prices.

In practice, it depends on a complex set of diffuse economic interactions which of the two indirect impacts described above occurs and to what extent. In most cases, it is likely that the increased demand for agricultural commodities for the biofuel sector results in both production increase and reduced consumption in the food sector.

The two main indirect impacts, ILUC and competition with food, are not by nature negative, but can very well cause unwanted effects. For example, the clearing of the forest as shown in Illustration 1 - 1 will release the carbon stocks stored in the forest vegetation and soil and will reduce biodiversity in the area. Competition with food can lead to decreased food consumption for groups of people who cannot afford the increased food prices. This effect is especially severe when it impacts the poorest groups of people that are already at risk of undernourishment.

## 1.2 Difficulties in assessing and mitigating indirect impacts

Indirect impacts of biofuel production are far more difficult to assess and mitigate than direct impacts. This is because they occur through market mechanisms that are generally beyond the control of the biofuel producer and consumer, whereas direct impacts are usually more obvious and easier to influence.

A few important notes on indirect impacts to further illustrate their difficult quantification and mitigation are:

- **Displacement effects act across national borders**: e.g. a shift in the oil palm produced in Malaysia from food to fuel could lead to an expansion of oil palm for food in Indonesia, with the accompanying risks of LUC.

- **Displacement effects act between substituting crops**: e.g. a shift in the rapeseed oil produced in the EU from food to fuel could lead to increased imports of a substituting vegetable oil, e.g. palm oil, for food. This puts additional pressure on oil palm expansion.
- **Competition for land connects also non-substituting crops**: e.g. high demand for maize may increase maize prices, leading to farmers planting more maize. This will mean less planting of another crop, e.g. soy. This could lead to an expansion of soy in other areas as a response to higher soy prices induced by the reduction in supply or additional pressures on soy-substituting crops.

The developments on mitigation of indirect impacts have suffered from the difficulty of assessing and influencing indirect impacts. Parties in favour of pursuing mitigation of indirect impacts claim that these impacts are so large they cannot be ignored in biofuel strategies and policies, while parties opposed to mitigation claim there is a lack of scientific consensus on indirect impacts that prevents development of accurate mitigation strategies and policies.

## 1.3 Aim and structure of this study

The Dutch government has played an important role in the (international) debate on biofuel sustainability, e.g. with the publication of the Cramer report[3] on sustainable use of biomass. It has subsequently contributed to policy development in this area on a national and international level. With the shift of attention towards the indirect impacts of biofuels, the Ministry of VROM has commissioned this study to:

- Review the technical literature and analytical tools that are being employed to quantify indirect impacts of biofuel production.
- Summarise existing regulatory and policy approaches to accounting for and mitigating global food price and indirect land use change impacts of biofuels production.
- Review current monitoring initiatives on indirect effects of biofuels.
- Make recommendations to the Ministry of VROM on the actions it can take to strengthen the international effort to prevent or reduce unwanted indirect impacts of biofuels.

This study addresses these goals in the following structure:

- Chapter 2 provides a review of a set of key (scientific) initiatives that aim to quantify the magnitude of the indirect impacts of biofuel production. It introduces the results of the studies performed by these initiatives and discusses key factors in methodology and assumptions that cause the differences in these results.
- Chapter 3 provides a review of current existing initiatives to account for and mitigate indirect impacts of biofuels production. It gives an introduction on each initiative and discusses its main mechanisms to give an insight into its possible effects.

[3] Project group "Sustainable production of biomass" (2007), Testing framework for sustainable biomass.

- Chapter 4 provides a review of current initiatives that monitor the indirect impacts of biofuels. It gives an introduction on each of the initiatives and analysis their ability to identify indirect impacts and link them to biofuel production.
- Chapter 5 provides recommendations to the Ministry of VROM on how to deal with indirect impacts and what options are available to incorporate mitigation measures in its policies.

# 2 Review of quantification initiatives of indirect impacts of biofuel production

*This chapter reviews a set of key (scientific) initiatives that aim to quantify the magnitude of the indirect impacts of biofuel production. This quantification, and therefore its review as well, is a rather complicated multi-step effort. Therefore the general stepwise methodology of this quantification and its review are addressed in section 2.1. The authors strongly advise to read this section, before continuing to the other sections of this chapter that contain the detailed information associated with this review and its results.*

## 2.1 Stepwise introduction to the quantification of indirect impacts

*In order to understand and interpret the quantification initiatives for indirect impacts and their methodology and results it is crucial to have an adequate understanding of the general developments in these initiatives. Therefore these are summarized in a stepwise introduction in this section. Sub points of each step give a short conclusion of the relevant findings of this study with regard to that step and refer to the sections of this chapter that present that particular step in more detail.*

1. As described in Chapter 1, negative indirect impacts of biofuel production have received increasing attention in recent years. As a result, biofuel stakeholders such as producers, governments and NGOs entered into a debate on what can be done to mitigate these negative indirect impacts. There is however a significant hurdle in this debate: ***no general consensus among biofuel stakeholders exists on whether these indirect impacts are actually significantly large and if so, how large exactly***.
2. This lack of consensus as described in the previous point led to the ***development of initiatives that set out to quantify the impact of future additional biofuel demand including some or all indirect impacts***.
   - This study has limited its scope to three indirect impacts: those on the life cycle green house gas balance of the biofuel due to indirect land use change, those on biodiversity due to indirect land use change and those on global food prices and food consumption. This is further discussed in section 2.2.
3. ***Some of the first initiatives based their quantification on relatively simple calculations based on aggregated recent historic data*** on biofuel feedstock sourcing and agricultural expansion, ***combined with assumptions on a number of crucial parameters*** such as future feedstock, co-product availability, likely land use change types and the associated lost carbon stocks.
   - In general, these initiatives lie outside the scope of this study. However, one of them, the iLUC Factor initiative, is discussed because it played a significant role in political sustainability considerations around the European

Renewable Energy Directive. This is done at the end of the chapter in section 2.9.

4 However, this type of quantification was on many occasions deemed too rough to provide insight into the complex issue of indirect impacts. Therefore ***existing complex (global) agroeconomic equilibrium models***, previously mostly used to predict future developments in food supply and trade flows, ***were increasingly used to model the reaction of the global economy to additional biofuel demand*** as their more detailed calculation was expected to be more accurate.

- The initiatives that are included in the review in this study are presented in section 2.2.
- The methodology used to perform quantification of indirect impacts with these models is discussed in section 2.3. This discussion includes a short general introduction to global agroeconomic equilibrium models.
- Although these global model calculations are far more elaborate and detailed in nature, this study finds that their results are largely determined by the same key input assumptions as those of the simple quantification efforts discussed in the previous point. These assumptions are discussed in section 2.4.

5 ***Over the past years, a number of (scientific) initiatives have published results of the quantification of indirect impacts of additional biofuel demand using global agro economic equilibrium models***. They have presented these results in publications that discuss their model methodology, key input assumptions and key output results. ***In general, indirect impacts are found to be significant***. For example, the indirect greenhouse gas emissions of biofuels are found to be in the range of about 30% - 100% of total emissions of a fossil reference fuel.

- Each initiative presents its results in its own way and on its own level of detail. Therefore, the review and comparison of these results in this study required a large effort to extract and prepare a number of key results such that they could be meaningfully compared. The methodology for doing so is introduced in section 2.5.
- The result of this comparison can be found in section 2.6.

6 These ***quantification initiatives using global agroeconomic models have in turn been criticized to be too pessimistic, especially on some crucial input assumptions*** on e.g. future yield developments, effects of co-products of biofuels and land use change types caused by agricultural expansion for biofuel feedstocks.

- This critique and its merits are discussed in section 2.10.

## 2.2 Scope of the review in this study

*Section 2.1 mentions two important choices on scope in this review: the indirect impacts taken into account and the quantification initiatives that have been reviewed. They are presented in this section.*

The following indirect impacts were taken into account:

1. Impact on the life cycle green house gas balance of the biofuel due to indirect land use change.
2. Impact on biodiversity due to indirect land use change.
3. Impact on global food prices and food consumption.

This scope was chosen before performing the review as these indirect impacts were expected to be most relevant and most studied. During the review it was found that impact on biodiversity was not specifically quantified in any of the reviewed initiatives, although some mean to include it in future work.

The following key quantification initiatives using global agroeconomic equilibrium models were reviewed (each initiative is preceded by its short name that is used to refer to it in the rest of this study):

1. EC: Work undertaken by European Commission.
2. RFS: US Renewable Fuels Standard (2nd version, RFS2), designed by the Environmental Protection Agency.
3. LCFS: Californian Low Carbon Fuel Standard, designed by the Californian Air Resources Board.
4. Searchinger: Work undertaken by Tim Searchinger, scholar and lecturer at Princeton University, et al.
5. IIASA, Work undertaken by IIASA, the International Institute for Applied Systems Analysis.
6. LEI: Work undertaken by LEI, the agroeconomical institute of Wageningen University and Research Centre.

The reference list in the end of this report provides an overview of the publications of each initiative that were reviewed. It is important to note that most initiatives, including RFS, LCFS and LEI are working on refining and expanding the modelling calculations reviewed in this study. These results are expected in the near future.

Unfortunately, it was found that the first initiative, that of the EC, has not yet resulted in quantitative results and could thus not be included in the quantitative comparison. The EC has issued two large quantification studies using global agroeconomic equilibrium models that are expected to generate results in the near future, but it is as of yet unclear when exactly. (EC, 2009)

Also, although the work of LEI has provided quantified results of indirect impacts of biofuel production, it has unfortunately not been possible to extract data from their work that would allow a useful quantitative comparison with the other initiatives. This is further explained in Appendix A.

In addition to the quantification initiatives that use global agroeconomic equilibrium models, one of the relatively simple calculations based on aggregated recent historic data, as mentioned in point 3 in section 2.1, is discussed in this chapter. This is the iLUC Factor initiative led by the Öko-Institut and supported by the German federal environment agency Umweltbundesambt. Section 2.9 discusses this initiative because it played a significant role in political sustainability considerations around the European Renewable Energy Directive.

## 2.3 Methodology of quantification and the role of equilibrium models

*Section 2.1 explains that the quantification of indirect impacts has generally been performed by using global agroeconomic equilibrium models in recent years. This section presents the general methodology used in such quantification initiatives and explains the role of the equilibrium models in this quantification.*

Each initiative has its own exact methodology for quantification of indirect impacts of biofuel production. However, a general four-step approach is commonly found in these methodologies. This approach is visualized in Illustration 2 - 2.

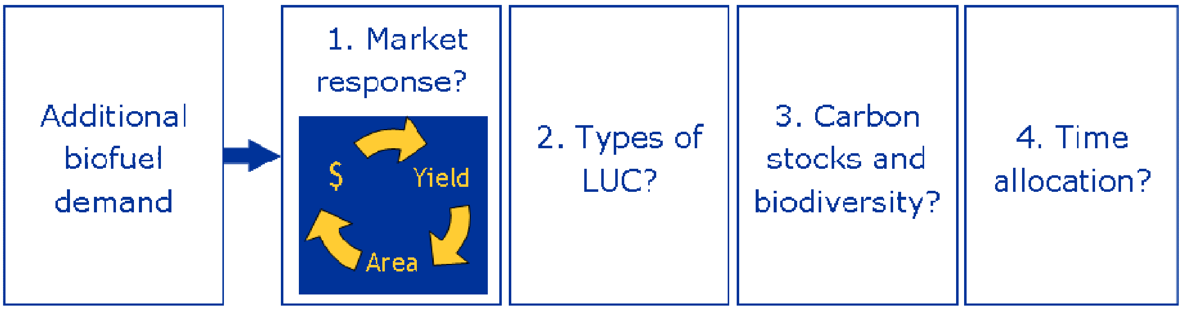


Illustration 2 - 2 Four-step approach to quantifying the indirect impacts of biofuel production. First a certain additional biofuel demand to be analyzed is chosen. Usually this is based upon a certain biofuel mandate, but it can also be based on general market expectations on competition with other fuels. Then the market response is calculated by modelling expected interdependent changes in commodity prices, crop yields and cropland areas due to the additional biofuel demand. To further quantify the effects of ILUC, information is gathered on types of LUC and the corresponding changes in carbon stocks and biodiversity. Finally, a time horizon is chosen to which these indirect impacts are allocated in order to enable comparison on e.g. a per year or per MJ fuel basis. This approach is described in more detail in Table 2 - 1.

The approach visualized in Illustration 2 - 2 can be used to quantify all the indirect impacts mentioned in section 2.2. This is further explained in Table 2 - 1.

| ***Step*** | ***Description*** | ***Reviewed impacts*** |
|---|---|---|
| 1. Market response | Global agroeconomic equilibrium models are used to assess the effect of additional biofuel demand, for example by introducing a biofuel mandate, on the market. Effects to accommodate the biofuel demand are usually separated in three categories:<br>• Expansion of agricultural land.<br>• Intensification of agricultural production; e.g. higher yield per harvest, increased number of harvests per year<br>• Higher commodity prices, crowding out consumers of the same commodity in other markets, leading to reduced consumption e.g. for food. | **Information on global food prices and food consumption** |
| 2. LUC | From step 1, it is known what amount of expansion of agricultural land can be expected. Also, the location is usually available on a country/region level. In this step a prediction is made on which types of land will be converted to agricultural land. One method used for this purpose is satellite analysis of historical LUC trends. | |
| 3a. Biodiversity<br>3b. Carbon stocks | Once the amount and the type of LUC is known from steps 1. and 2., the biodiversity and carbon stocks impacts can be assessed, making use of information sources on the carbon stocks and biodiversity values present in the LU-types that are converted – e.g. IPCC data-sources on carbon stocks. For the carbon impact, an additional step is needed, see step 4. | **Information on biodiversity loss** |
| 4. Time allocation | Although the carbon emissions quantified in step 3b. largely take place upon conversion, they are usually allocated to the GHG balance of biofuels in time. Different allocating mechanisms have been suggested. | **Information on life cycle GHG balance** |

Table 2 - 1 Detailed description of the methodology to quantify the indirect impacts of biofuel production on food consumption, biodiversity and biofuel life cycle GHG balance.

Not all initiatives encompass all the steps described in Illustration 2 - 2 and Table 2 - 1; in some cases only the first step, modelling the market response to the additional biofuel demand, is performed.

As mentioned in Table 2 - 1, step 1 is usually performed using global agroeconomic equilibrium models. These models, of which GTAP is an example, divide the world into certain regions or areas. The economic responses in these areas are predicted by combining a large amount of mathematical product functions with (historical) data from large databases. Within these product functions, the response of one parameter to a change in another parameter is described using elasticities. An example would be a function that describes how likely it is that if the price of importing a commodity increases that the imports of that commodity reduce. These elasticities can be based on historical data, expert judgment or a combination of the two.

The model always starts in a certain reference equilibrium state. Then, a distortion, e.g. an additional biofuel demand compared to the reference equilibrium state, is introduced. Using the product functions and the database data, the model then calculates a new, economically optimized, equilibrium state. The response to the distortion can then be determined by comparing the new equilibrium with the reference equilibrium.

Each specific model has its own regional divisions, product functions and elasticity assumptions. These differences in model setup and assumptions lead to differences in model outcomes ranging from minor to large. This paper does not discuss all the differences in setup and assumptions between the different models, but does provide a thorough analysis of those that have the largest impact on the model outcomes and thus on the quantification of indirect impacts. This is done in the sections 2.4 through 2.7.

## 2.4 Key assumptions in the quantification of indirect impacts

*Section 2.1 explains that although the global agroeconomic equilibrium models are far more complex and detailed than the simple calculations put forward in earlier quantification efforts, their outcome still very much depends on the same key input assumptions. This section presents these assumptions, discusses why they have such large effects on quantification outcomes and argues that a number of these key assumptions are difficult to quantify.*

The methodology of quantification described in section 2.3 contains a large and complex computational framework in the equilibrium models. This framework can however, as presented in Illustration 2 - 2 and Table 2 - 1, be described in four general steps. The main assumptions associated with each of these steps are thus determining factors in the eventual model outcomes. These are discussed here:

**1** Market response to additional biofuel demand

This step contains the following main assumptions to quantify the resulting cropland expansion, intensification of production and reduction of demand in other sectors.

- The **choice of feedstock** for the additional biofuel demand; e.g. including biofuel pathways with a high biofuel yield per hectare or biofuels from residues and wastes leads to lower indirect impacts.
    - Choosing biofuel pathways with a high biofuel yield per hectare means that in principle less area is needed to accommodate the additional biofuel demand and thus that indirect impacts are lower. As biofuel yields per hectare from high yielding pathways can be multiple times higher than those of low yielding pathways this can have a large effect. However, co-products should be taken into account as well; this is discussed in the next assumption.

- Choosing biofuel pathways from residues and wastes in principle puts no strain on the economic system, so no indirect impacts occur.
- This assumption is difficult to make because it is hard to predict for example future technological advances, market developments and residue and waste availability.

- Treatment of **co-products** of biofuel production.
  - Most biofuel feedstock crops do not only have biofuel as end-product, but co-products are produced as well. For example, corn used for ethanol production also yields residual dry distiller's grains and solubles (DDGS) commonly used as animal feed. And in soy biodiesel production the biofuel co-product, soy meal commonly used as animal feed, is even the main product in terms of volumes. These co-products can be accounted for by assuming they displace a certain amount of other commodities on the markets, usually animal feed. The assumption on how large this effect is, has a very significant effect on the outcome of the model. For example the DDGS from corn ethanol production is often assumed to replace one third of the original corn demand.
- **Relation between agricultural intensification and commodity prices and/or demand**.
  - This relation determines the amount of additional biofuel demand that is met through agricultural intensification. Any amount met this way does not need to be met by cropland expansion and thus no (I)LUC occurs for that amount.
  - This relation is very difficult to quantify: historical data is scarce and inconclusive, meaning that predicting future developments is difficult.
- **Relation between food demand and commodity prices**.
  - This relation determines the amount of additional biofuel demand that is met through reductions in food demand. Any amount met this way does not need to be met by cropland expansion and thus no (I)LUC occurs for that amount. In addition it determines the indirect impacts on food consumption.

**2** <u>LUC caused by cropland expansion</u>

- Assumptions of **types of LUC caused by cropland expansion**.
  - Since carbon stocks and biodiversity values between different land types, e.g. forest, grassland, savannah, can differ significantly; the type of land use change assumed to occur because of cropland expansion is a key parameter in quantifying indirect impacts.
  - Secondary indirect effects can occur in the cattle sector, which is not included in each modelling effort. For example when a biofuel is produced from soy previously used for the food sector, the soy might be replaced by an expansion into pastures used for cattle grazing. This cattle pasture might in turn be replaced by pasture expansion into a forested area. This

secondary effect is only quantified when the modelling effort accounts for these changes in the cattle sector.

**3** Current carbon stocks and biodiversity values of land used for cropland expansion

- Assumptions on **carbon stocks and biodiversity values** of land types affected by cropland expansion.
  - Even when the types of LUC are known from the second step, the carbon stock and biodiversity value of the land affected by LUC is still an important assumption, as different values are used within the different initiatives.

**4** Time allocation of GHG emissions of LUC

- Assumptions on **time allocation of GHG emission effects**.
  - Most GHG emissions of LUC occur soon after the conversion of land types takes place, for example by burning the original vegetation. However, in the final result of the GHG life cycle analysis of the biofuel, these emissions from LUC need to be allocated in time to the biofuel produced on the land. The amount of years chosen for that is not principally set, since it is not known for how many years the land will be used for biofuel production. This enables a very broad range of time horizons, commonly somewhere between 20 to 100 years, and thus has a significant effect on the indirect GHG impacts.

## 2.5 Methodology to compare the assumptions and results of the quantification

*From section 2.1, 2.3 and 2.4 it is clear that a custom comparison methodology was needed to compare the assumptions and the results from the different quantification initiatives. This methodology is described in this section.*

Results of the equilibrium modelling methodologies described in section 2.3 are usually presented in (scientific) publications. This necessarily limits the details that can be published. Unpublished parameters can sometimes be obtained by contacting the authors, but not all.

This limitation on the detail available necessitates careful construction of a method for comparison. In this study, a set of key parameters from each initiative was chosen to allow a good comparison of the main assumptions and results of the initiative, while still keeping collection of these parameters manageable.

The model input assumptions in this set of parameters represent the important assumptions described in section 2.4:

- A1: The amount and choice of feedstock for the additional biofuel demand.
- A2: Treatment of co-products of biofuel production.
- A3: Relation between agricultural intensification and commodity prices and/or demand.
- A4: Relations between commodity demand, commodity prices and food demand.
- A5: Emissions of cropland expansion, integrating:

    - Assumptions of types of LUC caused by cropland expansion.
    - Assumptions on carbon and biodiversity stocks of land types affected by cropland expansion.
- A6: Project horizon for emissions from (I)LUC

The model output results in this set of parameters contain crucial and comparable quantitative data on the magnitude of the calculated indirect impacts:

- R1: The division between the following possible results from additional biofuel demand:
    - Biofuel induced agricultural intensification
    - Reduced demand in other sectors
    - Cropland expansion
- R2: Absolute amount of cropland expansion.
- R3: GHG emissions of (I)LUC caused by cropland expansion.

Table 2 - 2 presents this set of parameters in more detail and describes their use in making the comparison. In some cases it was necessary to perform some calculations with the published data, for example to convert units or to categorize the data into the set of parameters chosen in this review. In section 2.6, when results are presented for which such calculations were necessary, their use is mentioned.

It is important to note that in most of the global agroeconomic models direct and indirect land use changes and thus their GHG effects can not be separated: the model calculates a reference scenario and an additional biofuel scenario for land uses. The differences between the two represent all land use changes, both direct and indirect. Therefore, these two are combined in Table 2 - 2 and the rest of this study.

It is also important to note that no specific parameters on biodiversity have been chosen: none of the initiatives was found to have done any dedicated analysis to this topic. Additionally, no common absolute parameter to express impacts on food consumption could be identified. However, indirect impacts on food consumption can be derived from the share of reduced demand in other sectors in the results of additional biofuel demand.

Table 2 - 2 Key parameters used in presenting the assumptions and results of the different quantification initiatives for indirect impacts for biofuel production, allowing a comparison between initiatives. Each parameter and its unit are given and an explanation is given on the use of this parameter in the comparison. Rows marked with a green shade contain model input assumptions, rows marked with a brown shade contain model output results.

| A/R[4] | Parameter | Unit | Explanation |
|---|---|---|---|
| | **Additional biofuel demand** | | **These parameters set what additional biofuel demand is assumed in the study and thus indicate the essential input to the modelling part.** |
| **A1** | Total | Mtoe | Total amount of additional biofuels when new and reference equilibrium are compared. Mtoe stands for megaton of oil equivalent, or the energy content of 1 million tons of fossil oil. 1 Mtoe corresponds to 41.9 PJ or roughly 2 billion liters of ethanol. |
| | From energy crops | Mtoe | Total amount of additional biofuels coming from biofuel pathways based on energy crops. Cropland expansion, agricultural intensification and/or reduced demand in other sectors are needed to obtain the feedstock. The differentiation between this category and the category of biofuels from residues and wastes is made to enable a more differentiated and fair comparison between indirect impacts per unit of additional biofuel demand. |
| | Feedstock division | % | The above amount is divided into shares of pathways per feedstock. |
| | From residues and wastes | Mtoe | Total amount of additional biofuels coming from biofuel pathways based on residues and wastes, e.g. corn stover. Because the used residues and wastes are already available, no cropland expansion, agricultural intensification and/or reduced demand in other sectors are needed to obtain the feedstock. The differentiation between this category and the category of biofuels from energy crops is made to enable a more |

[4] These codes refer to the assumptions and results discussed earlier in this section.

| | | | |
|---|---|---|---|
| | | | differentiated and fair comparison between indirect impacts per unit of additional biofuel demand. |
| | Feedstock division | % | The above amount is divided into shares of pathways per feedstock. |
| | **Treatment of co-products** | | |
| **A2** | | | Description of how co-products of biofuel production from the different feedstocks are handled in the model. Where possible the effect of the co-product is expressed in a quantitative displacement of the original feedstock. |
| | **Assumptions on additional agricultural intensification** | | |
| **A3** | | | Description of assumptions on the relation between agricultural intensification and commodity prices and/or demand. |
| | **Assumptions on changes in food demand** | | |
| **A4** | | | Description of assumptions on the relations between commodity demand, commodity prices and food demand. |
| | **Additional demand results in** | | **These parameters give a rough but clear indication what is predicted to result from the additional biofuel demand, which is the primary level of model output. It gives information on one of the three indirect impacts: food consumption.** |
| **R1** | Biofuel induced agricultural intensification (total) | % | % of total additional biofuel feedstock demand resulting in additional agricultural intensification in new equilibrium compared to the reference equilibrium. |
| | Reduced demands in other sectors (total) | % | % of total additional biofuel feedstock demand resulting in reduced demand in other sectors in new equilibrium compared to the reference equilibrium. |
| | Cropland expansion (total) | % | % of total additional biofuel feedstock demand resulting in cropland expansion in |

| | | | |
|---|---|---|---|
| | | | new equilibrium compared to the reference equilibrium. |
| | Biofuel induced agricultural intensification (from energy crops) | % | Idem, but then relative to the additional demand of biofuels from energy crops. |
| | Reduced demand in other sectors (from energy crops) | % | Idem, but then relative to the additional demand of biofuels from energy crops. |
| | Cropland expansion (from energy crops) | % | Idem, but then relative to the additional demand of biofuels from energy crops. |
| | **Extent of cropland expansion** | | **These parameters further describe the cropland expansion found in the model output. A large amount of cropland expansion is likely to lead to significant indirect impacts on biodiversity and the GHG balance.** |
| **R2** | Cropland expansion | Mha | The total amount of cropland expansion found. The number is expressed in Mha or megahectare. This amounts to 1 million hectares or 10,000 $km^2$. |
| | Cropland expansion (relative, total) | Ha/toe | The relative amount of cropland expansion found per unit of total additional biofuel demand. toe stands for ton of oil equivalent, or the energy content of one ton of fossil oil. 1 toe corresponds to 41.9 GJ or roughly 2,000 liters of ethanol. |
| | Cropland expansion (relative, from energy crops) | Ha/toe | The relative amount of cropland expansion found per unit of additional demand of biofuels from energy crops. |
| | **GHG effect of cropland expansion** | | **These parameters indicate how many greenhouse gas emissions in CO2 equivalents are associated with the land use change through cropland expansion. These can include released biomass carbon, soil carbon and forgone forest sequestration.** |
| **A5** | Weighted average of emissions from crop expansion | tCO2eq/ha | The amount of CO2 equivalents released per unit of cropland expansion. This is a weighted average between different types of land use change that are determined in the modelling and includes both direct LUC and ILUC as these effects are usually not |

| | | | |
|---|---|---|---|
| | | | separated in the models. tCO2eq stands for tons of CO2 equivalent. In this unit, all greenhouse gas emissions occurring are converted into an amount of CO2 emissions with an equivalent greenhouse gas effect. |
| **A6** | Project horizon for emissions from (I)LUC | Years | The amount of time over which the released CO2 equivalents that are mainly released upon land conversion are annualized. This is an important parameter for obtaining the GHG impact per unit of fuel produced. |
| **R3** | Weighted average of emissions from (I)LUC (total) | gCO2eq/MJ fuel | Combination of direct and indirect GHG impact per unit of total additional amount of biofuel, since direct and indirect GHG effects are usually not separated in the models. In this unit, all greenhouse gas emissions occurring are converted into an amount of CO2 emissions with an equivalent greenhouse gas effect. gCO2eq instead of tons and MJ instead of Mtoe are used because life cycle GHG emissions of (fossil) reference fuels are usually given in this unit. |
| | Weighted average of emissions from (I)LUC (from energy crops) | gCO2eq/MJ fuel | Idem, but then for the additional demand of biofuels from energy crops. |

Table 2 - 2 Key parameters used in presenting the assumptions and results of the different quantification initiatives for indirect impacts for biofuel production, allowing a comparison between initiatives. Each parameter and its unit are given and an explanation is given on the use of this parameter in the comparison. Each unit that is not self-explanatory is explained in the row where it first occurs. Rows marked with a green shade contain model input assumptions, rows marked with a brown shade contain model output results.

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Although the used global agro economic equilibrium models are complicated in nature, it is important to realize that the results R1 through R3 can in principle be obtained by simply combining the key assumptions A1 through A6. This is explained in Illustration 2 - 3.

***R1:***

- From A1 the additional amount of biofuel demand and the used feedstock is known.
- By adapting the needed amount of feedstock by including the effects of co-products from A2 a final amount of additional feedstock can be calculated.
- From this amount, by including the effects of A3 (intensification-price response) and A4 (food demand – price response) it can be found what the division in R1 (intensification, cropland expansion, reduced food consumption) is.

***R2:***

- From R1 it is known what part of the additional feedstock demand is met by cropland expansion. This relative amount can be translated to an absolute amount: R2.

***R3:***

- From R2 the absolute amount of cropland expansion is known.
- By multiplying this with A5 (GHG-emissions per unit of LUC) the total GHG emissions of LUC can be calculated.
- By dividing this number by the product of the annual amount of additional biofuels (A1) and the emission project horizon (A6), the GHG emissions of (I)LUC caused by cropland expansion per unit of fuel can be calculated, which is R3.

Illustration 2 - 3 Rough calculation methodology for calculating results R1 through R3 from assumptions A1 through A6 as presented in section 2.5.

## 2.6 Comparison of the assumptions and results of the quantification

Table 2 - 3 contains the assumptions and results of the quantification as reviewed according to the methodology presented in section 2.5.

Table 2 - 3 Comparison of the assumptions and results of the reviewed quantification initiatives of the indirect impacts of biofuel production. For an in-depth explanation of the result parameters and units, see Table 2 - 2. Rows marked with a green shade contain model input assumptions, rows marked with a brown shade contain model output results. The reference list in the end of this report provides an overview of the publications of each initiative that were reviewed.

| **A/R**[5] | | **Unit** | **RFS** | **LCFS** | **Searchinger** | **IIASA** | **LEI** |
|---|---|---|---|---|---|---|---|
| | **Additional biofuel demand** | | | | | | |
| **A1** | Total | Mtoe | 31.16 | 29.00 | 28.18 | 125.00 | Could not be determined from quantitative results, see main text. |
| | From energy crops | Mtoe | 16.71 | 29.00 | 28.18 | 125.00 | |
| | Feedstock division | % | 30% corn ethanol<br>6% soy biodiesel<br>28% sugarcane ethanol<br>36% switchgrass ethanol | 87% corn ethanol<br>13% sugarcane ethanol[6] | 100% corn ethanol | 78% ethanol<br>22% biodiesel | |
| | From residues and wastes | Mtoe | 14.45 | 0.00 | 0.00 | 0.00 | |
| | Feedstock division | % | 100% corn stover ethanol | N/A | N/A | N/A | |

[5] These codes refer to the assumptions and results as discussed in section 2.5.

[6] The LCFS work contains modeling on more feedstocks than corn and sugarcane, for example soy, however these values are reported as preliminary and are thus not included.

| | | | RFS | LCFS | Searchinger | IIASA | LEI[7] |
|---|---|---|---|---|---|---|---|
| | **Treatment of co-products** | | | | | | |
| **A2** | | | Co-products included endogenously in the model.<br>Corn: 25-45% displacement[8] of original feedstock by co-products.<br><br>Sugarcane, switchgrass and corn stover: 0% displacement, all co-products are used for process energy. | Corn: 25-45% displacement[8] of original feedstock by co-products;<br><br>Sugarcane: 0% displacement, all co-products are used for process energy. | Corn: 33% displacement of original feedstock by co-products. | Co-products included endogenously in the model, exact effect is unclear. | Co-products not included with any displacement effect. |
| | **Assumptions on additional agricultural intensification** | | | | | | |
| **A3** | | | Assumed to be zero regardless of demand and/or price increases of commodities. | Included in the model through various demand/yield elasticities. | Assumed to be zero regardless of demand and/or price increases of commodities. | Included in the model.[9] | Included in the model.[9] |
| | **Assumptions on changes in food demand.** | | | | | | |
| **A4** | | | Included in the models.[9] | | | | |

[7] The reasons to not include quantitative data of the LEI work are given in Appendix A.
[8] In this study the co-product of corn ethanol is assumed to replace corn on a ~1 : 1 weight basis. As generally 25% - 45% of the corn input ends up in the co-product, this range is used by Ecofys to estimate the co-product displacement effect.
[9] These assumptions consist of a large range of interacting assumptions that form the core of the equilibrium modeling and can thus not be summarized here.

| | | | RFS | LCFS | Searchinger | IIASA | LEI[10] |
|---|---|---|---|---|---|---|---|
| | **Additional demand results in** | | | | | | |
| **R1** | Biofuel induced agricultural intensification (total) | % | 0% | Could not be determined from quantitative results.[11] | 0% | 27%[12] | Could not be determined from quantitative results, see main text. |
| | Reduced demand in other sectors (total) | % | 3%[13] | | 20%[14] | 34% | |
| | Cropland expansion (total) | % | 97% | | 80% | 39% | |
| | Biofuel induced agricultural intensification (from energy crops) | % | 0% | | 0% | 27% | |
| | Reduced demand in other sectors (from energy crops) | % | 6% | | 20% | 34% | |
| | Cropland expansion (from energy crops) | % | 94% | | 80% | 39% | |

[10] The reasons to not include quantitative data of the LEI work are given in Appendix A.
[11] There was to few quantitative data on biofuel induced agricultural intensification and reduced demand in other sectors to quantify this division. Communication with authors of the LCFS work indicated that the effect of these two on reducing needed cropland expansion was significant, but no quantitative value could be reported.
[12] These values on division of results from additional demand were reported by IIASA to be valid for the cereals used as biofuel feedstock in their scenarios. As ethanol from cereals is the main contributor to the analysed scenarios, it is assumed to be valid for the entire additional biofuel demand.
[13] The values for reduced demand in other sectors in the RFS work were calculated by Ecofys based on values on worldwide reduced food consumption reported in the RFS work. This value is therefore of an indicative nature. Communication with the authors of the RFS work did confirm that they also believed the effect of demand reduction in other sectors to be small in their calculations.
[14] This value was an estimate as reported by Searchinger during personal communication with Ecofys and is therefore indicative.

| | | | RFS | LCFS | Searchinger | IIASA | LEI |
|---|---|---|---|---|---|---|---|
| | **Extent of cropland expansion** | | | | | | |
| **R2** | Cropland expansion | Mha | 4.9 | 5.0 | 10.8 | 21.5 | Could not be determined from quantitative results, see main text. |
| | Cropland expansion (relative, total) | ha/toe | 0.16 | 0.17 | 0.38 | 0.17 | |
| | Cropland expansion (relative, from energy crops) | ha/toe | 0.29 | 0.17 | 0.38 | 0.17 | |
| | **GHG effect of cropland expansion** | | | | | | |
| **A5** | Weighted average of emissions from crop expansion | tCO2eq/ ha | 288 | 235[15] | 351 | 219[16] | Was outside the scope of the LEI study. |
| **A6** | Project horizon for emissions from (I)LUC | Years | 30 | 30 | 30 | 30[17] | |
| **R3** | Weighted average of emissions from (I)LUC (total) | gCO2eq/ MJ fuel | 30[18] | 32 | 103 | 30 | |
| | Weighted average of emissions from (I)LUC (from energy crops) | gCO2eq/ MJ fuel | 56 | 32 | 103 | 30 | |

Table 2 - 3 Comparison of the assumptions and results of the reviewed quantification initiatives of the indirect impacts of biofuel production. For an in-depth explanation of the result parameters and units, see Table 2 - 2. Rows marked with a green shade contain model input assumptions, rows marked with a brown shade contain model output results. The reference list in the end of this report provides an overview of the publications of each initiative that were reviewed.

[15] This factor was back calculated from the weighted average GHG results in gCO2eq/MJ fuel as reported by the LCFS, since no conclusive direct data was found in the publications.
[16] This value is backcalculated from total GHG emissions of LUC reported by IIASA. As the entire quantification of these GHG effects is reported as indicative in the IIASA publications, this value is indicative as well.
[17] The IIASA study does not select a specific project horizon for emissions from (I)LUC. However, since IIASA scenario values for biofuel development in the period 2000 – 2030 were used in this review and to allow for easy comparison with the other studies, a 30 year horizon was used to calculate IIASA results.
[18] This factor is about 5-10% lower than the one that would be found by following the methodology in Illustration 2 - 3. This is because the factor reported in the RFS work also contains some beneficial indirect GHG impacts of biofuels like reduced methane emissions in the cattle sector.

## 2.7 Analysis of differences in results of the quantification

This section explains the differences found between the results of the reviewed initiatives presented in Table 2 - 3 in a detailed fashion. This is done on a topic-by-topic basis.

### 2.7.1 Additional biofuel demand

| | Unit | RFS | LCFS | Searchinger | IIASA |
|---|---|---|---|---|---|
| Total | Mtoe | 31.16 | 29.00 | 28.18 | 125.00 |
| From energy crops | Mtoe | 16.71 | 29.00 | 28.18 | 125.00 |
| Feedstock division | % | 30% corn ethanol<br>6% soy biodiesel<br>28% sugarcane ethanol<br>36% switchgrass ethanol | 87% corn ethanol<br>13% sugarcane ethanol[19] | 100% corn ethanol | 78% ethanol<br>22% biodiesel |
| From residues and wastes | Mtoe | 14.45 | 0.00 | 0.00 | 0.00 |
| Feedstock division | % | 100% corn stover ethanol | N/A | N/A | N/A |

The total amount of additional biofuel demand in the initiatives is comparable except for IIASA's, which is more than four times higher than that of others. Generally, the studies remark that results are not very sensitive to the absolute value of the additional biofuel demand, in other words: double the demand leads to double (in)direct impacts.

All additional biofuel demands are based on future biofuel growth expectations or mandates. A number of differences are important to mention:

- The RFS total includes about half of biofuels from residues and wastes; this is ethanol from corn stover, which is assumed to have no effect on land use.
- The RFS assumes a number of relatively high yielding pathways: sugarcane and switchgrass ethanol while the others base their analysis primarily on ethanol from corn or other cereals that usually have lower biofuel yields per hectare.

The feedstock choice is one of the multiple assumptions that have a significant impact on the overall modelling results of indirect impacts. Its influence on quantification results is discussed further in the other parts of this section.

[19] The LCFS work contains modeling on more feedstocks than corn and sugarcane, for example soy, however these values are reported as preliminary and are thus not included.

### 2.7.2 Results of additional biofuel demand

| | Unit | RFS | LCFS | Searchinger | IIASA |
|---|---|---|---|---|---|
| Biofuel induced agricultural intensification (total) | % | 0% | Could not be determined from quantitative results. | 0% | 27% |
| Reduced demand in other sectors (total) | % | 3% | | 20% | 34% |
| Cropland expansion (total) | % | 97% | | 80% | 39% |
| Biofuel induced agricultural intensification (from energy crops) | % | 0% | | 0% | 27% |
| Reduced demand in other sectors (from energy crops) | % | 6% | | 20% | 34% |
| Cropland expansion (from energy crops) | % | 94% | | 80% | 39% |

Key observations are:

- Both the RFS and Searchinger assume that no agricultural intensification is caused by the additional biofuel demand, so their results reflect this assumption, while IIASA finds that 27% of additional biofuel demand is met by a biofuel-induced intensification.
  - Searchinger gives an explanation of his assumption by noting that potential agricultural intensification due to higher demand and/or price is neutralized by the yield loss associated with taking into production of marginal lands that are less suitable for agriculture.
  - IIASA finds very significant agricultural intensification, mainly due to the fact that the number of yearly harvests on agricultural areas in developing countries is increased. This is a factor that it is not directly included in the other models.
- The RFS finds a very limited reduction in food consumption, while Searchingen and IIASA respectively find that 20% and 34% of additional biofuel feedstock demand is supplied from a reduction in food demand.
  - These differences are likely to be the effect of a different assumption on how prices react to an increase in demand and on the demand elasticities for food.

For the LCFS work quantitative values for biofuel induced agricultural intensification and reduced demand in other sectors are not available. However, personal communications with authors of the work suggests that their influence is significant, possibly limiting cropland expansion by around one third. Further details on this topic will be published in the future.

### 2.7.3 Extent of cropland expansion

| | Unit | RFS | LCFS | Searchinger | IIASA |
|---|---|---|---|---|---|
| Cropland expansion (relative, from energy crops) | ha/toe | 0.29 | 0.17 | 0.38 | 0.17 |

With respectively 0.38 and 0.29 ha/toe of cropland expansion per unit of additional demand biofuels from energy crops[20], Searchinger and RFS find reasonably comparable numbers. The lower value in the RFS work is caused by the fact that their additional demand includes high yielding crop pathways of sugarcane and switchgrass ethanol.[21]

The LCFS value and IIASA value are significantly lower than that of both Searchinger and the RFS. For IIASA this can be easily explained, since in their work only 39% of the additional biofuel demand is met through cropland expansion which is about half of the values between 80 and 95% in Searchinger and RFS, see section 2.7.2. This makes it fully understandable that as a result the cropland expansion number is also about half of that in the other studies.

For the lower LCFS number, the same explanation is likely but can not be completely verified, as explained in section 2.7.2.

### 2.7.4 GHG effect of cropland expansion

| | Unit | RFS | LCFS | Searchinger | IIASA |
|---|---|---|---|---|---|
| Weighted average of emissions from crop expansion | tCO2eq/ha | 288 | 235 | 351 | 219 |
| Project horizon for emissions from (I)LUC | Years | 30 | 30 | 30 | 30 |

The chosen project horizon is the same in each of the three initiatives, so this does not lead to differences. Although the emissions from LUC through crop expansion are in the same order of magnitude, a difference is still noticeable with the range going from 219 to 351 tCO2eq/ha. This range can be explained by the assumptions the different initiatives make in these areas:

[20] The most useful parameter to compare in this category is the relative cropland expansion per unit of additional demand biofuels from energy crops. This choice is made because biofuels from residues and wastes are assumed to be produced from feedstocks that are already available in the reference scenario. Including them in this comparison would spread the indirect impacts of biofuels from energy crops over a larger total, leading to an underestimation of their impact.

[21] Searchinger and the RFS find virtually identical cropland expansion factors for corn ethanol, since their assumptions on yield and the displacement effect of co-products of corn are very similar. However, the RFS includes three additional energy crop pathways (sugarcane ethanol, switchgrass ethanol, and a small amount of soy biodiesel). Since the biofuel yields per hectare of the sugarcane and switchgrass pathways (even after accounting for co-product effects) are assumed to be significantly higher than that of corn the land displacement effects of these feedstocks are found to be ~20% and ~70% lower respectively. On average, the RFS fuel mix should therefore lead to a ~30% lower relative cropland expansion which is very much in line with the reported values.

- Searchinger assumes that all deforestation historically found in a certain area is caused by cropland expansion, provided that cropland expansion has historically been larger than deforestation. Through this assumption he finds large LUC in forested areas. Since forests are rich in carbon compared to land types with less vegetation, this leads to the highest emission per ha converted in the found range.
- The RFS uses historical data on types of direct LUC caused by cropland expansion from satellite imagery. These data indicate a significantly lower share of LUC in forested areas than in Searchinger's work. However, the RFS calculation assumes a secondary effect where some of the pastureland replaced by biofuels will be reclaimed by deforestation, leading to an additional indirect deforestation and associated carbon emissions. Overall, this leads to the second highest value of emissions per ha converted in the found range.
- The LCFS model has an intrinsic part that models the types of LUC that occur. According to the modellers, this part uses both historic data as well as endogenous optimization of land value to specify the predicted types of LUC. The model methodology does not allow for secondary shifts in LUC, for example the reclamation of a pasture that was displaced by biofuel feedstock production in a forested area. Using this methodology, the model calculates that most LUC occurs on pastures/grasslands with relatively low carbon stocks. Therefore, the LCFS finds the second lowest value for emissions per ha converted.
- The IIASA study only states that IPCC carbon stock values have been used, but does not give a detailed quantified breakdown. In addition, the entire GHG emission part of the study is stated to be indicative only. In total this means that is unclear why this study finds the lowest value for emissions per ha converted.

### 2.7.5 GHG emissions caused by (I)LUC

| | Unit | RFS | LCFS | Searchinger | IIASA |
|---|---|---|---|---|---|
| Weighted average of emissions from (I)LUC (from energy crops) | gCO2eq/MJ fuel | 56 | 32 | 103 | 30 |

It is most useful to compare the greenhouse gas emissions equivalents associated with (I)LUC per unit of additional demand of biofuels from energy crops. These differences of GHG emissions caused by (I)LUC per unit of fuel are in fact an accumulation of the differences in the other parameters as described in the previous sections, see Illustration 2 - 3. From this framework the results for this parameter can be fully explained.

- The IIASA and LCFS work find the lowest and almost equal values of 30 and 32 gCO2eq/MJ respectively. This is caused by the fact that they find both low relative cropland expansion per unit of additional biofuel demand and low emissions per ha of expanded cropland as discussed in sections 2.7.3 and 2.7.4.

- The RFS work finds roughly 50% higher values for cropland expansion per unit of biofuel and one third higher values for emissions per unit of expansion compared to IIASA and LCFS. This would suggest a factor two higher GHG emissions per unit of fuel at ~60 gCO2eq/MJ fuel. This is very much in line with the actual result of 56 gCO2eq/MJ fuel, when taking into account that this value is 5 – 10% lower than expected because some beneficial indirect impacts[22] on GHG emissions are included in the RFS work.
- Compared to the LCFS and IIASA work, the work of Searchinger finds values more than twice as high for cropland expansion per unit of biofuel and just over one half higher for emissions per unit of expansion. This would suggest a factor 3.5 higher GHG emissions per unit of fuel, which again is very much in line with the results.

## 2.8 Conclusions on the comparison of the reviewed quantification initiatives

The conclusion from the comparison between the reviewed quantification initiatives in this chapter has three important elements:

- No quantitative information on indirect impacts on biodiversity is available; quantitative information on food consumption is limited.
- There are very significant differences between the quantifications of the indirect impacts of biofuels on land use changes and associated carbon emissions. The impacts on the GHG balances of the fuels, range from 30 to 103 gCO2eq/MJ fuel, more than a factor of three in difference. However, it is important to note that we found in section 2.7 that these differences in opinion between the different reviewed initiatives do not stem from a radically different approach of the problem but in a few key quantitative assumptions. The most important of these assumptions, discussed in detail in section 2.4, are:
    - The choice of feedstock for the additional biofuel demand
    - Substitution effects of biofuel co-products
    - Relation between agricultural intensification and commodity prices and/or demand.
    - Relations between commodity demand, commodity prices and food demand.
    - Assumptions of types of LUC caused by cropland expansion.
    - Assumptions on carbon stocks of land types affected by cropland expansion.
- Even though there are differences between the values of the quantitative outcomes, all studies in this review find that the indirect impacts of biofuels are

[22] For example reduced methane emissions in the rice and cattle industry due to reduced demand for their products.

quite large. For example, the impacts on the GHG balance range from about 30% to > 100% of a fossil reference[23]. In each case, indirect impacts are one of the larger, or the largest factor in the overall GHG balance. This makes it easier to assess the need for pragmatic mitigation efforts, even though there is a broad range of theoretical quantification results available.

## 2.9 The iLUC Factor quantification approach

The iLUC Factor quantification approach is a relatively simple approach used by the Öko-Institut to quantify potential indirect GHG impacts of biofuels. Instead of using global agroeconomic models to predict economic response to additional biofuel demand, a relatively simple calculation is made. The iLUC Factor is discussed here because it was used to calculate the GHG bonus of 29 gCO2eq/MJ awarded for feedstock cultivation on severely degraded or heavily contaminated land as included in the European Renewable Energy Directive. This section first discusses the general quantification approach of the iLUC Factor and the example calculation that yielded the 29 gCO2eq/MJ result. Then it discusses how the iLUC Factor compares to the modelling initiatives discussed in the earlier parts of this chapter and how the iLUC Factor is meant to be applied. The sources studied on the iLUC Factor are mentioned in the References chapter.

The iLUC Factor quantification methodology is based on a stepwise approach. This approach is a simple calculations based on assumptions and historic data. Each set of assumptions leads to a different outcome. The methodology and the example calculation leading to the 29 gCO2eq/MJ result are shown in Table 2 - 4.

| Step | Description | Value in 29 gCO2eq/MJ example |
|---|---|---|
| 1 | **Assumption on average GHG emission factor per hectare of land subject to land use change.**<br><br>This is done based on specifying four land use change types and assuming the likelihood of their occurrence through data on global trade patterns. A value of 400 tCO2eq/ha is found which is set for all iLUC Factor calculations. | 400 tCO2eq/ha |
| 2 | **Assumption on allocation period for land conversion GHG emissions.**<br><br>This is done based on IPCC conventions and is set for all iLUC Factor calculations to be 20 years. | 20 years |

[23] Depending on the exact fossil reference used, these life cycle GHG emissions are usually around 80 – 90 gCO2eq/MJ fuel.

| | | |
|---|---|---|
| 3 | **Calculation of annual GHG emission factor per hectare of land converted.**<br><br>This is done by dividing the results of the previous two steps. | 20 tCO2eq/ha/y |
| 4 | **Assumption on likelihood of indirect land use change actually occurring**<br><br>Not all additional biofuel demand is assumed to lead to indirect land use change. For example, agricultural intensification and feedstock grown on degraded land can prevent this. A range of 25 – 75% likelihood is assumed for the occurrence of indirect land use change. | 25% |
| 5 | **Assumption on yield of the specific biofuel route in question**<br><br>In this step, a feedstock specific biofuel yield per hectare per year is assumed. | 170 GJ/ha/y<br><br>(for biofuels from switchgrass or short rotation coppice) |
| 6 | **Calculation of the iLUC Factor**<br><br>The iLUC Factor gCO2eq/MJ is calculated using the result and assumptions from the previous three steps. | 29 gCO2eq/MJ<br><br>(= 20 tCO2eq/ha/y * 25% / 170 GJ/ha/y) |

Table 2 - 4 iLUC Factor quantification methodology and example calculation leading to the 29 gCO2eq/MJ result.

When the iLUC Factor approach is compared to the global agroeconomic modelling approaches in a qualitative way, two crucial differences can be found:

1. The iLUC Factor makes a simple assumption for the likelihood of an indirect land use change effect occurring. This is a model output, instead of an assumption, in the modelling approaches.
2. The iLUC Factor makes one set assumption on the average GHG emission factor per hectare of land subject to land use change. In the modelling approaches, this is based on the regions and sometimes land types where indirect land use change effects are predicted to occur according to the model output.

In a quantitative comparison of the results of both approaches, the following important points are found:

- The GHG emission factor per hectare converted in the iLUC Factor is 400 tCO2eq/ha. This is higher than the 219 – 351 tCO2eq/ha range found in the modelling approaches.
- The allocation period is set at 20 years, which is lower than the 30 years used in the modelling approaches.

- The likelihood of an indirect land use change effect occurring is 25 – 75% which is quite low compared to the 39 – 94% range found in the modelling approaches. Especially the 25% leading to the 29 gCO2eq/MJ result is low compared to the modelling outcomes. This has to do with more optimistic assumptions on the effects of agricultural intensification and use of degraded land for feedstock growing.
- The final result of iLUC Factor calculations depends strongly on the assumptions of biofuel yield and likelihood of an indirect land use change effect occurring. It can for example range from 29 gCO2eq/MJ for more optimistic assumptions (25% indirect land use change, 170 GJ/ha/y yield) to 300 gCO2eq/MJ for more conservative assumptions (75% indirect land use change, 50 GJ/ha/y yield). Therefore the iLUC factor results can basically span at least the entire 30 – 103 gCO2eq/MJ range found for (I)LUC GHG impacts in the modelling approaches.

The iLUC Factor is meant to only incorporate ILUC GHG impacts. GHG impacts of direct LUC are additional and a dLUC Factor is calculated to account for those. Whether or not both the iLUC Factor and the dLUC Factor are applied to a specific case depends on the land type that is going to be used for feedstock growing. For example, expansion on degraded lands is subject only to a dLUC Factor, not an iLUC Factor. However, expansion on existing cropland does not receive a dLUC Factor, but does receive an iLUC Factor. This forms another difference with most modelling approaches that generally do not distinguish between emissions from dLUC and iLUC but report the average overall emissions from direct and indirect LUC combined.

### 2.10 Critique on quantification initiatives as those reviewed in this study

As concluded in section 2.8; although the exact numbers differ considerably, all initiatives reviewed in this study find indirect impacts of biofuels to be significant. However, some parties claim that indirect impacts either:

1. Should not be attributed to biofuels at all, or;
2. Are much smaller or even insignificant compared to what was found in this review

For the first claim, one of the frequently heard arguments is that indirect impacts should not be attributed to biofuels because they actually consist of direct impacts in other sectors. Therefore mitigation of these impacts should occur by regulating these sectors where the direct impacts take place and not by imposing restrictions on the biofuels sector. On the other hand, it is important to note that the biofuel industry primarily exists because of support by policies that usually have a goal to reduce GHG emissions. Because of this special status of the biofuel sector, it would not be unreasonable to also include indirect impacts in assessing whether biofuels actually contribute to this goal. This is not a clear-cut debate and a position should be developed by VROM on this matter.

A second argument that is used to support the first claim is that there is no scientific consensus on the magnitude of indirect impacts. While this could indeed be concluded from the wide range of e.g. indirect impacts on GHG emissions resulting from the different quantification initiatives reviewed, the fact that they all find the indirect impacts to be significant supports the idea that pragmatic mitigation would have positive effects.

Three arguments are mainly used regarding the second claim. They directly tie in to the potential reaction of the global economic system to an additional biofuel demand as depicted in Illustration 2 - 2. These arguments are:

1. Model predictions of ILUC caused by biofuels have been proven wrong by available historic data on cropland expansion.
2. Co-products of biofuel production displace so much demand for other agricultural commodities that the net cropland expansion and impact on food consumption caused by biofuels is very low.
3. Agricultural intensification caused by additional biofuel demand accounts for such a large part of the additional feedstock needed that the net cropland expansion and impact on food consumption caused by biofuels is very low.

The first argument makes use of the fact that historically expansion of agricultural cropland has not directly caused deforestation as can for example be found from satellite data. While this might be true, the argument ignores the indirect nature of indirect impacts of biofuel production. In other words: even if (biofuel) cropland itself expands on e.g. pastures, it is still possible that it indirectly leads to deforestation as new replacement pastures are created by cattle owners. This diffuse, indirect effect makes this argument invalid

The second argument relies on the fact that co-products of biofuel production displace other agricultural commodities and thus indirectly displace the need for land to grow these commodities. For example when DDGS displaces crops used in animal feed. Some parties claim that this substitution is of a very high magnitude (e.g. 90%), for example because the co-product is assumed to replace a low yield animal feed crop or because the nutritional value of the co-product is assumed to be much higher than that of other animal feed varieties. While it is almost certain that displacement in fact occurs, values of up to 90% are far beyond the range of assumptions in the models in this review that are between 0 – 45% as can be seen in Table 2 - 3.

The third argument relies on the fact that an additional biofuel demand could lead to a (relative) increase in crop prices and/or margins. These in turn could be a strong incentive for agricultural intensification to optimize returns. It is true that yields of some crops have increased significantly over the past decades and by looking selectively at the data, very high intensification predictions can be constructed that imply a significant reduction in the need for additional land of even up to 100%.

However, these values are far higher than the values found in the initiatives reviewed in this study, which range from 0 to 27%.

Concluding, it can be said that the main arguments used to claim that ILUC effects of biofuels are small, are based on assumptions on key parameters that are well outside the range found in any of the scientific initiatives reviewed here. We have not analysed the validity of these assumptions, or the ones made in the reviewed initiatives, in this study.

# 3 Review of current mitigation measures for indirect impacts of biofuel production

*Most of the current work on indirect impacts of biofuel production is focused on quantification of the problem, as discussed in chapter 2. While understanding the magnitude of the problem is clearly relevant, this should be complemented by an understanding of how biofuels can be produced without (or with a minimum risk of) indirect impacts. Relatively few concrete initiatives exist today that aim to mitigate the indirect impacts of biofuels. The initiatives that do exist and their main characteristics are analysed in this chapter. Before discussing the individual initiatives, section 3.1 first sets out a common framework for the analysis. Then, in section 3.2 a summary of the existing individual initiatives and their characteristics is given. In sections 3.3 through 3.7 the individual initiatives are analyzed in detail for a number of important characteristics.*

## 3.1 Mitigating indirect impacts

This section sets out a common framework for analyzing mitigation measures for indirect impacts of biofuel production. First, it refers to a number of key characteristical difficulties of mitigating indirect impacts discussed earlier. Then it discerns between mitigation measures at the global and the project level. Finally, it introduces a general outline of options available for individual producers to mitigate indirect impacts on the project level.

### 3.1.1 Key characteristic difficulties of mitigating indirect impacts

To be able to assess the effectiveness of proposed measures against indirect impacts from biofuels, several key characteristics of indirect impacts need to be understood. These have been presented earlier in chapter 1, primarily in section 1.2, being:

- Displacement effects act across national borders
- Displacement effects act between substituting crops
- Competition for land connects also non-substituting crops
- Competition with food and indirect land use change are closely related

### 3.1.2 Global versus project-level mitigation measures

In theory, three types of mitigation measures are available to prevent or minimise unwanted indirect impacts from biofuels. The first two concern global mitigation measures, while the third describes project-level mitigation measures:

1 **Prevent unwanted direct LUC, globally and for all sectors.** Unwanted ILUC from biofuels manifests itself through unwanted *direct* LUC for the production of agricultural products for other sectors such as the food and feed sector, as

described in section 1.1 and Illustration 1 - 1. Preventing unwanted direct LUC would thus eliminate unwanted ILUC altogether. Note that because of the international characteristics of ILUC and the competition for land between different sectors, this mitigation measure requires global implementation for all land-intensive sectors to be effective. In addition, it should be noted that preventing unwanted direct LUC, like deforestation, in non-biofuel sectors, could in turn lead to higher food prices, which can also be undesired.[24] To conclude it can be said that while a potentially worthy mitigation measure for the longer term, this mitigation measure is unlikely to fully materialize in the short to medium term and is largely outside of the influence of individual actors.

2 **Reduce pressure on land from the agricultural sector as a whole by increasing yields, supply chain efficiencies and/or a reduction in consumption**[25], e.g. through increased public R&D or policy incentives. This could reduce the need for expanding the area used for agricultural production[26]. However, a globally constant or shrinking agricultural area does not necessarily prevent unwanted LUC. Shifts in land used for agricultural production (without a net increase in the total area) can still cause unwanted LUC. Also this mitigation measure is unlikely to materialize in the near future, with projections from leading agricultural institutions indicating an expanding agricultural area during the next decades. It also lies largely outside of the influence of individual actors.

3 **Practical production models that prevent indirect impacts at a project level**. While the other two mitigation measures take a more macro approach (in which governments are likely to be key actors) this approach focuses on the role individual producers can play (in the absence of the above two mitigation measures.) This includes mitigation measures such as the much debated production on "idle land". Such mitigation measures are more amendable to a certification approach as they focus on individual producers. They are discussed in more detail in section 3.1.3.

### 3.1.3 Preventing indirect impacts at the project level – what individual producers can do

Four main mitigation measures at the project level have been put forward to expand biomass usage for energy purposes without unwanted consequences from indirect impacts (Ecofys 2007a, Ecofys 2008, RFA 2008, Woods 2008). They are presented here:

[24] IIASA has carried out a modeling study which indeed found that food prices increased more in a scenario with additional biofuel demand and a ban on deforestation than in a scenario without such a ban on deforestation.
[25] As in the first option, decreasing food demand is not always a desired option itself.
[26] Such measures could be taken independent of biofuels policies as well. One could argue that without biofuels such measures would actually free up agricultural land that could revert back to e.g. forest, thereby potentially offering carbon and biodiversity benefits. Using such areas for biofuels could be seen as having an 'opportunity' cost in foregone carbon sequestration or increase in biodiversity. We do not discuss this matter in more detail here.

1 Producing biofuels from **residues**. The use of residues as biofuel feedstock can displace current functions and uses of these residues, e.g. soil enhancing functions of agricultural residues or industrial process fuel use of waste fats and oils. This could therefore lead to negative indirect impacts by necessary replacements of the residues by e.g. additional fertilizer inputs or fossil process fuels. Therefore, current functions and uses of these residues must be well understood when pursuing this mitigation measure, which is currently not always the case.

2 Producing biofuels from **aquatic biomass** such as algae. Specific sustainability aspects for such production (e.g. increasing pressure on the coastal environment) also need to be taken into account.

3 Producing biofuels from **feedstock grown on land without provisioning services**[27] e.g. land where no food production or cattle grazing takes place. Because this does not displace existing provisioning services it does not cause an indirect LUC. Clearly, expanding production on unused land does lead to a direct LUC, with potential unwanted social and/or environmental consequences. The big advantage is that direct LUC is controllable (e.g. through certification) and can be limited to those areas where effects are acceptable, while the effects of indirect LUC are diffuse and uncontrollable. Often an area is not completely "unused" and a sliding scale exists between this "unused land" concept and the "intensification" concept in the next bullet.

4 Introducing energy crop cultivation without displacing the original land use through agricultural **intensification** or integration models. In developing countries especially there is a significant potential for yield improvements by e.g. increasing the yield per harvest, increasing the amount of harvests or intensifying cattle raising. The positive effects of using this potential would reduce agricultural land requirements. Potential negative environmental or social impacts from intensification models such as increased use of fertiliser have to be taken into consideration as well.

## 3.2 Summary of existing mitigation initiatives

This section gives a summary of the existing mitigation initiatives for indirect impacts from biofuels. First, the two main characteristics on which each initiative is analysed are presented. Then, a table gives a summary of the various initiatives and provides a first rough analysis on the two main characteristics. In sections 3.3 through 3.7 the individual initiatives are analyzed in detail on a number of important characteristics.

[27] The Milliennium Ecosystem Assessment distinguishes four categories of ecosystem services: provisioning services, regulation services, cultural services and supporting services. Provisioning services are defined as harvestable goods such as fish, timber, bush meat, genetic material, etc. (Commission for Environmental Assessment, 2006). This is also commonly referred to as "degraded land", "marginal land", "waste land" or "abandonned land".

### 3.2.1 Main characteristics used in analysis of mitigation initiatives

- Scope: is the measure focused at GHG effects only or also on other measures such as biodiversity and food consumption?
- Behavioural change: does the measure provide concrete incentives for behavioural change by the actors involved in biofuel production and consumption? This can be relevant on two levels: First: are actors driven to choose a certain feedstock with a lower risk of indirect impacts? Second: are actors that are committed to a certain feedstock driven to make choices in their production process that eliminate or minimize risks on indirect impacts?

### 3.2.2 Summary of the various mitigation initiatives and their characteristics

Table 3 - 1 shows a summary of the various initiatives that have proposed or are developing proposals for measures to mitigate indirect impacts from biofuels. Detailed analysis is provided in sections 3.3 through 3.7.

| | Measure | Scope | Drives behavioural change | |
|---|---|---|---|---|
| | | | **Feedstock choice** | **For a given feedstock** |
| **RFS – US Renewable Fuels Standard** | GHG-factor | GHG | + | - |
| **LCFS – Californian Low Carbon Fuel Standard** | GHG-factor | GHG | + | - |
| **RCA – Responsible Cultivation Areas (Ecofys et al.)** | Preventing displacement by expanding on land without provisioning services | GHG<br>Biodiversity<br>Land rights<br>Food consumption | + | + |
| **RCA – Responsible Cultivation Areas (Ecofys et al.)** | Preventing displacement through agricultural intensification | GHG<br>Biodiversity<br>Land rights<br>Food consumption | + | + |
| **EU RED – EU Renewable Energy Directive** | Various alternatives are being considered | | | |

| | |
|---|---|
| **UK RTFO – UK Renewable Transport Fuel Obligation** | Under development |

Table 3 - 1 Summary of the various initiatives that have proposed or are developing proposals for measures to mitigate indirect impacts from biofuels. For each initiative the main measure and its scope are given. Also, it is indicated with a +/- score whether the initiative is likely to drive behavioural change of actors as described in section 3.2.1. Detailed analysis is provided in sections 3.3 through 3.7.

## 3.3 Detailed analysis of mitigation initiative: RFS

### 3.3.1 RFS and indirect impacts

The Renewable Fuels Standard is a federal biofuel obligation in the United States that consists of various components for different "types" of biofuels. Currently a second version, also referred to as RFS2 is being developed. In the RFS different pre-defined biofuel chains (e.g. corn ethanol) are categorized based on their feedstock and GHG-performance. It is proposed that the GHG performance is calculated with a life cycle analysis that includes a pre-determined amount of emissions from ILUC thus including ILUC in the characterisation of a particular pathway for a biofuel.

The total GHG impacts from ILUC[28] for biofuels from different energy crops are roughly the same magnitude at around 55 g$CO_2$eq/MJ, with a weighted average of 58 g$CO_2$eq/MJ. When these indirect impacts are taken into account, GHG savings by biofuels compared to fossil fuels are about 60% lower than when indirect impacts are not taken into account.[29]

Note that the RFS is still under development and it is uncertain whether GHG-effects from ILUC will be included once its final version is adopted.

### 3.3.2 Scope

The RFS focuses on GHG savings and for ILUC the proposal includes only the GHG effects. While this may have close links with effects on biodiversity and food consumption, measures to mitigate unwanted effects on these aspects are not explicitly included in the RFS.

[28] In the RFS calculations, total carbon emission values for a combination of direct LUC and ILUC are calculated, since they can not be separated from each other in the modeling approach. These combined effects are meant here when ILUC is mentioned.
[29] Soy-based biodiesel is an exception with ILUC emissions around 70 gCO2eq/MJ and a reduced savings of about 80%

### 3.3.3 Incentives for behavioural change

The emissions from ILUC have a significant impact on the GHG emissions of a biofuel pathway in the RFS, and thereby on the type of biofuel the pathway is categorized into. As the RFS requires that a certain part of the total target is met though biofuels with a high GHG saving, it provides a concrete incentive for biofuel types without emissions from ILUC, such as biofuels from residues. In other words, the RFS contains an incentive for producers to choose a feedstock with little or no emissions from ILUC.

However, for a given feedstock, producers can not prevent or lessen the GHG effect from ILUC by taking additional measures to prevent or reduce the risk of ILUC, because it is a standard, pre-determined amount coming from the life cycle calculations done within the RFS. Thereby, for a given feedstock the RFS does not provide any incentives for producers to change their behaviour such as to minimize the risk of ILUC.

## 3.4 Detailed analysis of mitigation initiative: LCFS

### 3.4.1 LCFS and indirect impacts

California's Low Carbon Fuel Standard (LCFS) adopted by the Air Resources Board on April 23, 2009 requires a 10% reduction in the average greenhouse gas emission intensity of the State's transportation fuels by 2020. Biofuels are expected to play a major role in achieving these targets.

The GHG savings of biofuels compared to the fossil reference fuels is determined through an LCA of pre-defined biofuel chains. Emissions from ILUC are included in this the LCA. Thereby the scheme provides incentives for biofuels that cause no or less ILUC. Currently, calculations have been done for a few different pre-defined biofuel chains fed by energy crops. The GHG emissions from ILUC for these chains[30] under the LCFS are rather constant, at around 30 - 46 $gCO_2eq/MJ$, or around 31-47% of the fossil reference fuel. Additional pre-defined biofuel chains will be calculated in the future.

### 3.4.2 Scope

The focus of the LCFS is on GHG emissions and therefore only GHG effects from ILUC are currently within the scope of the LCFS. Discussions are ongoing on including wider social and environmental sustainability aspects.

[30] In the LCFS calculations, total carbon emission values for a combination of direct LUC and ILUC are calculated, since they can not be separated from each other in the modeling approach. These combined effects are meant here when ILUC is mentioned.

### 3.4.3 Incentives for behavioural change

As for the RFS, the LCFS provides an incentive for biofuel producers to use feedstocks that have little or no emissions from ILUC. Currently, as the RFS, the LCFS does not give clear guidelines that a biofuel producer can follow on project level, after a feedstock has been chosen, to prevent indirect impacts. As a result, in the current LCFS it is not possible for an individual producer to avoid having to take the standard value for indirect impacts into account in his GHG balance. Therefore no incentive for implementing effective ways to mitigate indirect impacts exists. However, the LCFS has indicated that this is subject to further investigation and consultation in the future and that, as a result, regulation on this might be implemented.

## 3.5 Detailed analysis of mitigation initiative: EU Renewable Energy Directive

The EU Renewable Energy Directive (RED) contains a 10% target for renewable energy in transport, in which biofuels are expected to play an important role. Only biofuels that meet certain sustainability criteria count towards this target. These sustainability criteria primarily cover GHG emissions from the entire fuel chain, and carbon stock and biodiversity effects from direct LUC. The RED currently does not contain explicit measures aimed at reducing unwanted indirect impacts. However, the RED states that before the end of 2010 the EC shall report on the indirect impacts of biofuels including proposals on how to minimize unwanted indirect impacts. The report shall, if appropriate, be accompanied by a concrete proposal including the GHG effects of ILUC in the GHG methodology of the RED.

The EC recently consulted on a number of options for dealing with indirect impacts from biofuels, presented in the textbox in Illustration 3 - 1. In terms of the main options discussed in section 3.1.2, these range from tackling direct LUC in other sectors like food and feed to including GHG emissions from ILUC into the biofuel life cycle analysis as the RFS and LCFS do.

A. Extend to other commodities/countries the restrictions on land use change that will be imposed on biofuels consumed in the European Union

B. International agreements on protecting carbon-rich habitats

C. Do nothing

D. Increase the minimum required level of greenhouse gas savings

E. Extending the use of bonuses

F. Additional sustainability requirements for biofuels from crops/areas whose production is liable to lead to a high level of damaging land use change

G. Include an indirect land use change factor in greenhouse gas calculations for biofuels

Illustration 3 - 1 Different options for dealing with indirect impacts as recently included by the European Committee in a first consultation round among stakeholders.

Not all these options are worked out in detail yet, making it impossible to make a detailed analysis of their effectiveness in preventing ILUC at this stage and to predict which of these options, and possible other alternatives, will be considered for the RED. However, it is possible to give a general indication of the potential strengths and weaknesses of each option.

Options A and B, addressing the general issue of (I)LUC for all sectors in all countries, are good options for the long term. However, these options are unlikely to effectively prevent ILUC in the short term (e.g. during the RED mandate period of 2010 – 2020) because their effectiveness depends on the participation of all countries. Mobilising this participation is generally a time-consuming and difficult process. It could also lead to additional increases in food prices, see also section 3.1.2.

Option C of course gives no incentive to mitigate indirect impacts. It could be argued that the required level of GHG savings in the RED provides an automatic ‘cushion’ to deal with indirect impacts, should the savings be larger than the indirect impacts on the GHG balance. However, this is rather uncertain and even then it would still be desirable to mitigate indirect impacts. In addition, other indirect impacts on e.g. biodiversity and food consumption are not addressed. For option D, even if the minimum required level of greenhouse gas savings is increased, the same weak points remain.

Option E of giving a GHG bonus to biofuels that do not or are unlikely to cause indirect impacts could in general provide an incentive to prevent indirect impacts. However, it also has serious weaknesses. First of all, producers of biofuels that score well enough on direct impacts, will not need the indirect impact bonus to be considered eligible under the RED and will thus not have an incentive to mitigate indirect impacts. In addition, if a biofuel obtains a bonus, it will be attributed with GHG savings that are not actually realized, which is illogical.

Option F is potentially effective, however is very difficult if not impossible to implement because of the diffuse nature or indirect impacts as also summarized in section 1.2. This makes it nearly impossible to link these impacts to "crops/areas whose production is liable to lead to a high level of damaging land use change". Even if this could be done, the effectiveness of the measure would still depend on the set "additional sustainability requirements".

Option G could be effective, but it very strongly depends on potential methodology for individual producers to avoid getting the factor applied in their life cycle GHG balance, otherwise there would be no incentive to pursue mitigation. Also, only applying a factor to the GHG balance does not address other indirect impacts like those on biodiversity and food consumption.

## 3.6 Detailed analysis of mitigation initiative: UK Renewable Fuels Agency

Since April 2008, the UK Renewable Transport Fuel Obligation (RTFO) is the world's first government biofuel obligation that has an operational biofuel sustainability scheme in place. The scheme works largely through the use of existing certification schemes such as the RSPO[31] and ACCS[32] to ensure sustainable feedstock production. Schemes like these have a history of engaging and consulting stakeholders to define and verify sustainable feedstock production. Using their certification schemes within the RTFO makes the RTFO pragmatic, trustworthy and easier to implement. This mechanism to ensure sustainable feedstock production is combined with a separate approach for the GHG performance of the full chain. Indirect effects are currently not included in the RTFO.

The Renewable Fuels Agency, the administrative body of the RTFO, coordinated the Gallagher review on the indirect impacts of biofuels in 2008. One of the conclusions of the Gallagher review was that certain types of biofuel production have smaller risks of unwanted indirect impacts. These include biofuels from true residues as well as biofuels from appropriately defined "idle land" and from areas with a biofuel-induced agricultural intensification.

As a follow up to the Gallagher review, the RFA has recently commissioned two studies. First, the RFA asked Ecofys and Winrock to collect evidence of concrete case studies of such production models that have no or a reduced risk of unwanted indirect impacts, and to propose a practical methodology to acknowledge such biofuel production with a reduced risk of ILUC. If possible, such a methodology could

[31] Roundtable on Sustainable Palm Oil.
[32] Assured Combinable Crops Scheme.

be considered for use in the RTFO and other biofuel programs. First results are expected in October 2009.

Secondly, a study has been started in which the use of residues for biofuel production is analysed for its indirect impacts. This is done because a number of so called “residues” that could be used for biofuel production are now used in other (energy) applications. For example, tallow and other animal fats are sometimes used as process fuel. Should they be used for biofuel production, then their use as process fuel is displaced and needs to be met by other, likely fossil, fuels. The RFA study aims to investigate which residues can be used without causing such displacement effects and work toward criteria to select such residues. The consultancy work is carried out by a consortium led by Ecometrica. Results are expected in October 2009.

## 3.7 Detailed analysis of mitigation initiative: Responsible Cultivation Areas

### 3.7.1 Responsible Cultivation Areas and indirect impacts

The Responsible Cultivation Area initiative is a private sector initiative coordinated by Ecofys in collaboration with NGOs such as WWF and Conservation International and industrial parties such as Shell and Neste Oil. The initiative started in 2008 with the overarching goal to:

> *Identify areas and/or production models that can be used for environmentally and socially responsible energy crop cultivation, without causing unwanted displacement effects. (Ecofys 2009)*

The initiative provides a set of criteria that together define the requirements for RCAs, and a methodology for identifying RCAs. The draft criteria are included in Appendix B. For both the criteria and the methodology, the initiative draws upon existing standards and methodologies, most notably the EU RED, UK RTFO, RSB, CDM and the HCV-concept.

The initiative focuses on providing project-level solutions for producers that want to minimize the risk of ILUC. Thereby, the initiative focuses on two of the options introduced in section 3.1.2:

1. Expanding production on land without provisioning services
2. Increasing land productivity.

These solutions are best illustrated with practical examples - see Appendix C.

The initiative currently has a draft methodology that is being piloted in Indonesia (palm oil) and Brazil (sugarcane and palm oil).

### 3.7.2 Scope

The central concept of the RCA initiative is to expand agricultural production for biofuels without displacing other provisioning services of the land.[33] This would prevent all the potential consequences, such as effects on biodiversity or carbon stocks, of such displacement. Unwanted effects on food consumption should also be prevented as no food or feed production is displaced, thereby preventing shortages in the food/feed sector.

### 3.7.3 Incentives for behavioural change

The RCA concept includes concrete incentives for producers to change their behaviour. Producers are requested to cultivate their feedstock either on lands without provisioning services (while also meeting biodiversity, carbon stock and land right criteria) or to increase the productivity of the land, e.g. by integrating food and fuel production (see concrete examples in Appendix C).

The RCA concept is feedstock neutral. This means that, in principle, all feedstocks could meet the RCA-criteria. However, for some feedstocks this may be easier than for others. For example, perennial crops will more easily satisfy the criterion that losses of carbon stocks should be compensated, since perennial crops often have neutral or even positive effects on soil carbon.

## 3.8 Conclusion on current mitigation measures

Three main conclusions can be drawn on current mitigation measures for indirect impacts of biofuel production:

- The amount of mitigation measures that currently exists is small. In addition, of this small amount of measures most are not yet fully operational or are even still in development stage.
- Most of the mitigation measures that are in more advanced development focus only on GHG effects of indirect impacts of biofuels by incorporating an ILUC factor in the general life cycle analysis of feedstock-based biofuel pathways. This has the inherent limitation that there is no incentive for options to mitigate indirect impacts on the project level, given a certain feedstock.
- The RCA initiative and the RTFO initiative are the first to work on pragmatic solutions for feedstock production that has no or a minimized risk of indirect impacts by preventing displacement effects from occurring.

[33] Within the development of the RCA, but also in other developments, an debate has been raised on the effectiveness of expanding on land without provisioning services or 'idle land'. A more elaborate discussion of this debate and its links to the RCA initiative are presented in Appendix D.

# 4 Review of current monitoring initiatives of indirect impacts of biofuel production

*In this chapter we look at initiatives that aim to monitor the (indirect) impacts of biofuel production. These initiatives are relatively scarce and we identified only two. Before discussing these initiatives, we will first discuss the challenge of actual monitoring of direct and indirect effects of biofuels.*

## 4.1 The challenge of monitoring the impacts of biofuel production

Monitoring the direct and indirect impacts of biofuel production is challenging. The main reasons for this are discussed below.

### 4.1.1 Challenges in monitoring of direct effects

Monitoring of the *direct* impacts of biofuel production has at least two challenges. First, one must be able to measure the actual impacts, e.g. biodiversity loss, pollution, land right conflicts. Secondly, one must be able to link these impacts to biofuel production.

The first challenge relates to data availability on actual impacts such as biodiversity loss. Currently, data availability on many of these impacts is poor, as discussed in the next section.

The second challenge relates to at least two issues. The first is the fact that observable impacts such as deforestation often have a complex set of underlying drivers. It is therefore difficult to relate impacts such as deforestation directly to biofuel feedstock production (relation b in the graph below). The second issue is caused by the characteristics of the biofuel feedstock markets. Agricultural commodities such as vegetable oils and cereals are traded in large quantities in which the production from many different farmers or plantations is mixed. It is therefore often not possible to indicate from which farm or plantation the feedstock that is used in the actual biofuel production process originated (relation a in the graph below). This would require a track-and-trace system throughout the supply chain which is currently not in place and which is also not foreseen in the near future[34].

[34] The EU Renewable Energy Directive requires operators to use a so called Mass Balance system. Without going into the details of such a system, it does not provide traceability of the actual physical feedstock to individual farms or plantations.

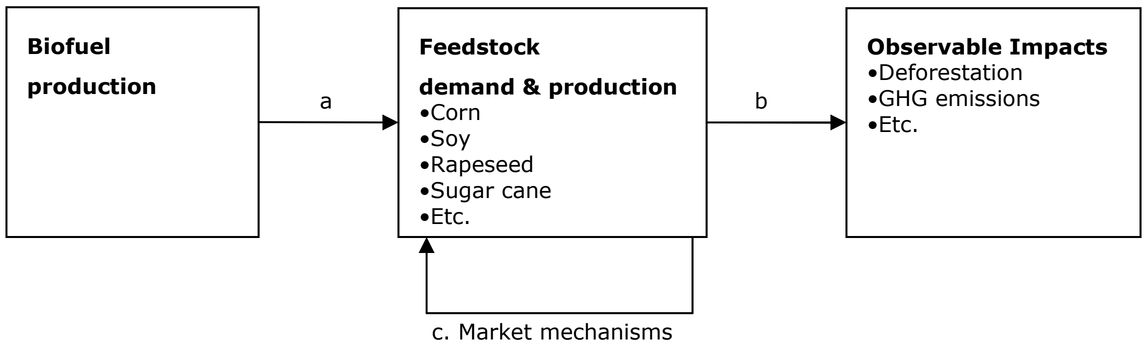


Illustration 4 - 2 Strongly simplified relationships between biofuel production and feedstock demand & production (a), feedstock demand & production and observable impacts such as deforestation (b), and interactions between different agricultural markets through market mechanisms (c).

### 4.1.2 Challenges in monitoring of indirect effects

The previous section shows that monitoring the *direct* impacts of biofuel production is already challenging. The monitoring of *indirect* impacts of biofuel production is even more challenging. The main reason for this is that the actual impact takes place in a different location to the actual biofuel feedstock production – driven by market mechanisms (relation c in the above graph). This makes it even harder to link the impacts to biofuel production.

A concrete example of the challenge of actually monitoring the indirect impacts of biofuels is a scenario where deforestation (the observable impact) is caused by food production that has been displaced by biofuel feedstock production. The fact that the two events are only linked through diffuse market mechanisms makes it impossible to link the biofuel feedstock production in one area to the deforestation in another area through a geographically explicit chain of events.

The same holds true for food prices that are also an impact that is the result of market mechanisms. Changes in food prices themselves can be observed, but to link them to biofuel production is extremely challenging and can often not be done through observable indicators.

The two examples above illustrate that linking indirect impacts such as food prices to biofuel production often requires modelling in addition to pure monitoring. When such modelling is used one can no longer speak of actual monitoring of the indirect impacts of biofuel production. The role of this modelling in the analysis can be reduced through monitoring of indicators that provide an insight in the workings of these market mechanisms (e.g. reduced EU-imports of soy meal as a result of increased DDGS production, a co-product of wheat to ethanol production.)

### 4.2 Data availability

The basis for monitoring the impacts of biofuel production is observable indicators, such as deforestation. This requires data collection on relevant indicators. The Netherlands Environmental Assessment Agency made an inventory of available data sources on the sustainability impacts of biofuel production in 2008 at the request of the Ministry of VROM. Table 4 - 2 gives an overview of the relevant data sources they identified. To our knowledge, this situation has not changed significantly since the publication of the report a year ago.

In line with the analysis in section 4.1, the report concludes that several factors hamper the assessment of the direct and indirect effects of biofuel production:

- The necessary data on impacts is only partly available.
- Most impact statistics do not distinguish between impacts caused by biofuels and impacts caused by other drivers such as feed and food production.
- The causal relationship between increased biofuel production and the impact on human well-being and the environment is not well established as human well-being and the environment are also influenced by many other factors.

The future availability of data may improve through policy initiatives such as the Renewable Energy Directive in the EU that requires much more information from biofuel suppliers on their feedstock sources. When the Directive comes into force by the end of 2010, governments may receive more information on where and how biofuels are produced. This may enable a better assessment of the direct impact of biofuel production. However no firm conclusions can be drawn yet on the usefulness of this information for the monitoring of indirect impacts of biofuels production because it is not yet known what exact information will become available to Member States. In addition, as indicated in the previous section, a Mass Balance system as a chain of custody does not provide traceability of the actual physical feedstock to individual farms or plantations. Full monitoring of direct impacts will therefore still not be possible. It will however be an improvement compared to the current situation, where global trade data is combined with high level indicators on social and environmental impacts. The data that may become available will not give information on the indirect effects, because biofuel producers can and have to only supply information that is directly related to their biofuel production.

| Sustainability criteria | National/international data | Source | Sub-national data | Source |
|---|---|---|---|---|
| *Greenhouse gas balance:* | | | | |
| Carbon stock | National Inventory Report | UNFCCC | Satellite data | SARVision/ WinRock International |
| Soil carbon | National Inventory Report | UNFCCC | *Not available* | / |
| Fertiliser use | FAOSTAT | FAO | *Not available* | / |
| *Biodiversity:* | | | | |
| Land use | Land use maps | NASA, ESA | Satellite data | SARVision |
| Protected areas | Map of protected areas | UNEP-WCMC | Satellite data | SARVision |
| Forestry | Forestry data (FAOSTAT) | FAO/WRI | Satellite data | SARVision |
| Agricultural areas | Arable and pasture | FAO | Satellite data | SARVision |
| High biodiversity value | *Not available* | / | High Conservation Value per country | High Conservation Value Network |
| Water use and quality | *Not available* | / | *Not available* | / |
| Endangered species | Red list species | IUCN | *Not available* | / |
| *Competition with food:* | | | | |
| Food and energy prices | FAOSTAT and IEA | FAO and IEA | Case studies | BEFS |
| Land use change | National statistics | UNFCCC/FAO | Satellite data | SARVision |
| *Prosperity:* | | | | |
| Production of bioenergy | National statistics | F.O. Licht and IEA | Case studies | / |
| Profit of bioenergy companies | *Not freely available* | / | Case studies | / |
| Income distribution | World Development Indicators National statistics | World Bank | Case studies | / |
| Trade flows | | F.O. Licht and IEA | Case studies | / |
| *Social well-being:* | | | | |
| Property rights | *Partly available* | / | *Methodology needs to be developed* | / |
| Impact on human rights | *Partly available* | / | | / |
| Wages and compensation rules | *Partly available* | / | | |
| Legal contracts | *Partly available* | / | | |
| Worker's rights | *Partly available* | / | | |
| Extent of forced labour | *Partly available* | / | | |
| Extent of child labour | *Partly available* | / | | |

Table 4 - 2 Summary of the availability of data for monitoring purposes, based on the Cramer criteria (Netherlands Environmental Assessment Agency, 2008).

## 4.3 Initiatives monitoring ILUC

Whereas modelling exercises are taking place in a number of places to calculate indirect effects (see chapter 2), few monitoring projects exist to our knowledge that aim to actually observe such indirect effects. Two are relevant to mention in this case. First Both ENDS runs a project on macro effects in Indonesia and Brazil, supported by the Dutch Ministry of VROM. The final results of this project are not yet available - preliminary results are discussed below. The second project is the Canasat project in Brazil. Other projects on the monitoring of indirect effects of biofuel production are not known to us.

### 4.3.1 Both ENDS project

Although the final results of this project have not yet been published at the time of writing, some assessment of the project is possible by looking at the project proposal and the presentation of some of the results during a meeting for experts.[35]

The project aims to identify macro-effects of biomass through a dialog with Civil Society Organisations (CSO) in biofuel-feedstock-producing countries. In its approach it does not only consider ILUC but takes into account all indirect effect (macro-effects) that could potentially be attributed to biofuels. It thereby uses the description of macro-effects of the Cramer Commission report on sustainable bioenergy.[36] Macro-effects are defined as the cumulative effects caused by increased use of bioenergy that can not be attributed to a single producer. The aim of the Both ENDS project is to gain more insight into the macro-effects as established in the Cramer report through case studies.[37] It also aims to develop a practical approach to identify macro-effects.

**Results of the Both ENDS project**

The project gathered information on macro-effects through a (limited) survey of experts, a case study in Brazil and a case study in Indonesia. For this purpose, it has set up a dialog with CSO's in Indonesia and Brazil, who are asked to identify these effects in their local area. The textbox of Illustration 4 - 3 summarises their main results.

[35] This meeting took place on the 20th of August 2009 in the Netherland. We have based our assessment on the slides presented during this meeting.
[36] Project group "Sustainable production of biomass" (2007), Testing framework for sustainable biomass.
[37] The Cramer report identifies several of this macro-effects: land prices; food prices; land ownership; availability of food; movement of food and cattle production; deforestation and loss of habitats due to food production; changes in vegetation.

*The case study on macro-effects in Brazil came to the following conclusions:*

- New economic cycle of re-occupation/re-organisation in rural areas
- Occupation by sugarcane of high quality land with characteristics favourable to grain production
- Emergence of some conflicts between grain and sugarcane sectors over land
- Sugarcane has taken over beef cattle land
- Redesign of local and regional policies in areas of expansion

The conclusion on the expansion of sugarcane is in line with the finding of the Canasat project, discussed in the next section.

*The case study in Indonesia identified macro-effects in four areas:*

- Agrarian justice: (1) Lack of mitigation measures to protect rights to land in plantation development; (2) Lack of new legal framework on agrarian reform; and (3) Lack of safeguard to secure status and ownership of lands.
- Energy sovereignty: (1) Biofuel industry would not contribute to cheap accessible energy; (2) Biofuel projects would not increase peoples' access to energy; (3) Energy Self-Sufficient Village provides inadequate energy for rural peoples.
- Water rights: (1) reduced water consumption (per capita); (2) pollution in rivers and water resources by agrofuels and their processing mills; (3) conversion of riparian; and (4) no access to watershed areas under use rights (HGU).
- Food sovereignty: (1) no guarantee that the government will stop converting/allocating agricultural lands to agrofuels; (2) no guarantee of food sovereignty of the government; (3) Indonesia only has concept of food security; (4) no guarantee of recognition of indigenous peoples' subsistent agricultures; and (5) food security strategy is not based on priority.

Illustration 4 - 3 Preliminary results of the Both ENDS project. (source: Presentation given at the expert meeting on 20 August 2009 in the Netherlands.)

**Ability to analyse ILUC**

We are not able to analyse the final results of the Both ENDS project. What we can do is assess whether the intermediate results provide information on ILUC and other indirect effects. Our conclusion is that the monitoring of indirect effects in the Both ENDS project is limited. From the information available to us we conclude that their effort to identify macro-effects only focuses on the impact side of the biofuel chain (the right-hand boxes in Illustration 4 - 2). This has three key consequences:

- **The link between biofuel policy and production is unclear.** No information was available on the link between EU biofuels policy (the biofuel target) and the increased production in the case study countries. Although it is made clear that

- both countries are selected because they are major producers and exporters of biofuel feedstock, this information is insufficient to establish a clear relationship between the EU biofuel policy and increased production in these countries.
- **The contribution of biofuels to the impacts is not made clear.** The identified impacts described are local impacts associated with agriculture. They occur with feedstock production for biofuels, but are not typical for biofuel itself. It is unclear what role biofuels play in shaping these impacts in relation to other sectors that make use of the same feedstock.
- **The effects described are likely direct and not indirect.** It is not possible to identify the indirect effects when looking only at the impact side (i.e. local case studies). The identification of indirect effects also requires an understanding of the market mechanism in order to identify indirect effects.

We do not have enough information available on the project to analyse whether the above mentioned concerns are dealt with in a sufficient manner. Based on the available information of the Both ENDS project we have to conclude that the identified effects of palm oil and sugarcane production are relevant to consider but that it is unclear a) how these observed effects cab be attributed to biofuels and b) to what extent they exclude important *indirect* effects that may occur in other locations.

### 4.3.2 The Canasat project

This project assesses the expansion of sugarcane in the Brazilian South Central Region. It is carried out by the Brazilian National Institute for Space Research (INPE) together with a number of Brazilian partner organisations.

Based on satellite remote sensing images the sugarcane area is monitored over time. The expansion of sugarcane is measured by comparing the sugarcane area in two consecutive years. The information includes both new plantations and the renovation of old plantations.

#### Results of the Canasat project

Illustration 4 - 4 shows the size of the sugarcane area and growth rate in a number of Brazilian provinces.

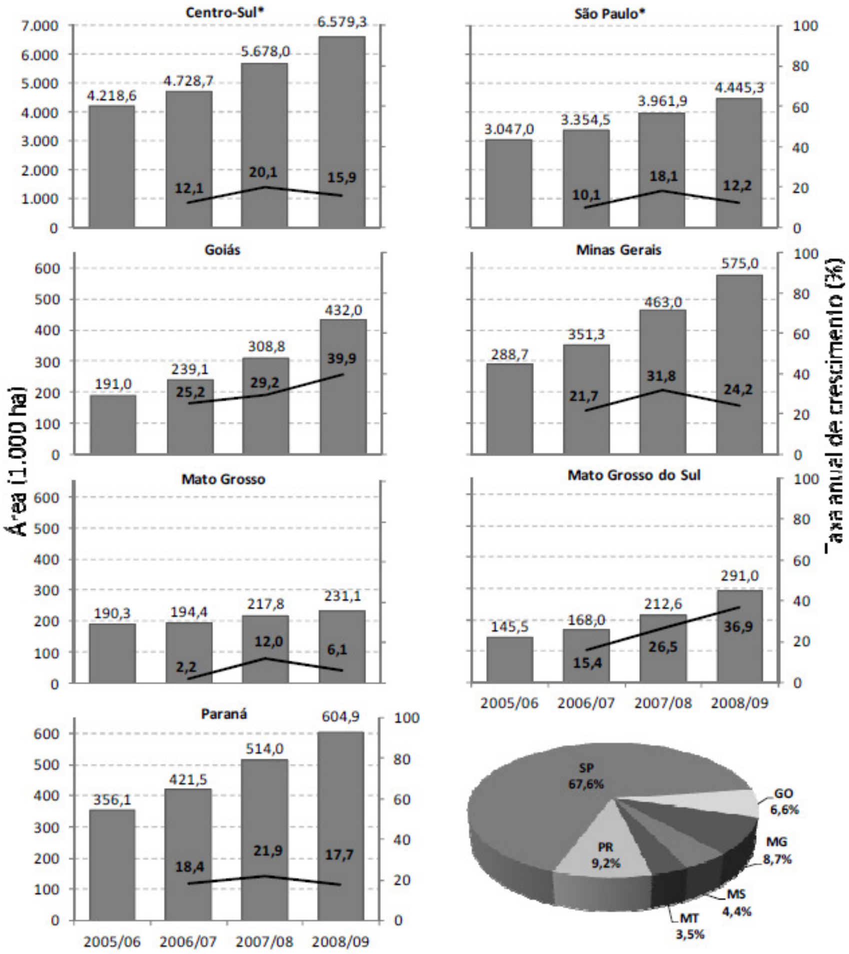


Illustration 4 - 4 Sugarcane area and annual growth rate for crop year 2004/05 and 2008/09.
Source: Presentation of Bernardo Rudorff (INPE), São Paulo, 20/11/2008

The figure clearly shows that sugarcane is expanding in all the provinces covered by the analysis. The data also shows that nearly all expansion of sugarcane takes place in the existing agricultural area, through the conversion of existing agricultural land and pastures (see Illustration 4 - 5 for Sao Paulo).

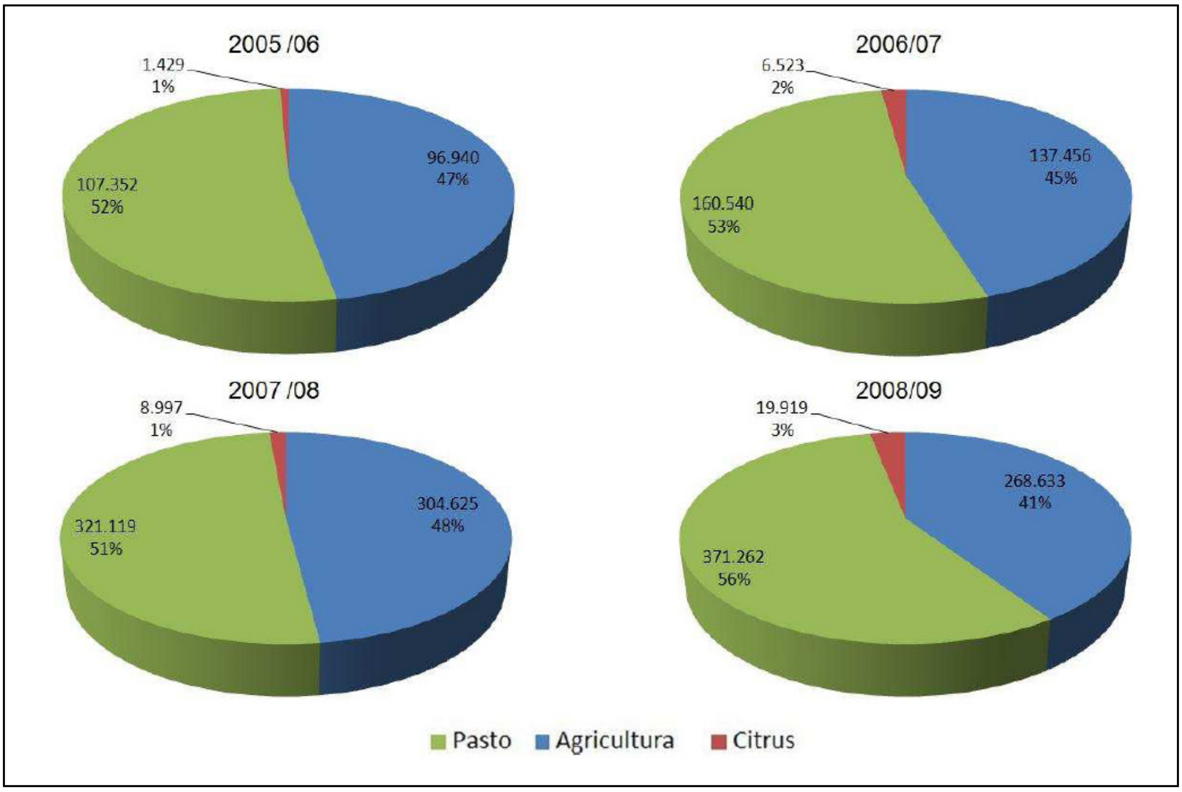


Illustration 4 - 5 Type of land use class that is converted to sugarcane from 2005 to 2008. Explanation: Pasto: Pasture; Agricultura: Agricultural land; Citrus: Citrus plantations. Source: Presentation of Bernardo Rudorff (INPE), São Paulo, 20/11/2008

**Ability to analyse ILUC**

The Canasat project identified the expansion rate of sugarcane plantations on an annual basis in the Brazilian South Central region through the monitoring of land use change. The project was also able to identify the type of land that was converted to sugarcane.

From this data the project rightly concludes that in the assessed regions sugarcane does not expand into natural areas directly. Nearly all of the converted areas are existing agricultural lands and pastures. However, at the same time, this is an indication that displacement takes place, which may cause indirect effects. (See chapter 1 for explanation of this process.)

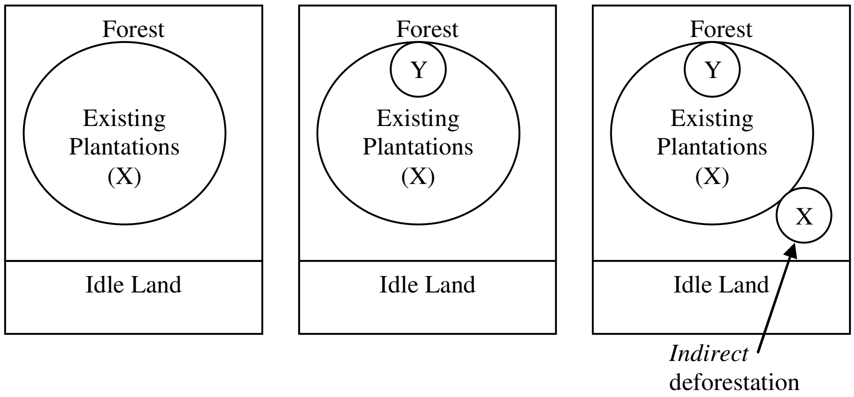


Illustration 4 - 6 Example of displacement mechanism causing indirect deforestation. Y is new demand from the bioenergy sector from existing plantations. X is expansion of existing plantations as a result of displacement effects. (Dehue, 2006). This illustration is a repeat of Illustration 1 - 1.

In relation to the example in Illustration 4 - 6, the Canasat project is able to identify the expansion of sugarcane on existing lands (Y in the middle figure). This project is not able to identify what the effects are of this: e.g. a relocation of the original production (X in the above illustration), a yield increase for the displaced crops or pasture, or a reduced food consumption.

The Canasat project has not considered these aspects and indicates that many questions are still unanswered about indirect effects. In relation to Illustration 4 - 2 it has focused its analysis on the middle box (production of feedstock). It does not include the other elements required for the identification of indirect effects of biofuels.

## 4.4 Conclusions on current monitoring projects

The main conclusions on monitoring of the (indirect) effects of biofuel production are that it hardly takes place today and that actual observation of indirect effects from biofuels will be extremely challenging if not impossible.

We reviewed two projects that aim to monitor direct and/or indirect impacts of biofuel production and found that both are currently unable to identify the indirect effects of biofuel production. The reason for this is that both projects only focus on one part of the chain through which indirect effects take place. The Both ENDS project focuses on the impacts caused by feedstock production that is also used for biofuels, but can not attribute (a specific part) of these effects to biofuels. The Canasat project shows that sugarcane mostly expands into areas where it displaces other agricultural uses of the land, but it does not address what effects this may have (in other locations). This selective focus of both projects is not sufficient to identify the indirect effects of biofuel production. This requires a full understanding of the whole chain of events that together lead to the indirect effects of biofuel production.

In addition, the identification of indirect impacts of biofuel production will always require a certain amount of modelling and can not be observed directly. This is because indirect impacts take place through market mechanisms which can not be observed directly. The role of this modelling in the analysis can be reduced through monitoring of indicators that provide an insight in the workings of these market mechanisms (e.g. reduced EU-imports of soy meal as a result of increased DDGS production, a co-product of wheat to ethanol production.) Information from producers that will become available through the Renewable Energy Directive may help this process.

# 5 Recommendations for the Ministry of VROM to strengthen the international effort to reduce the indirect impacts of biofuel production

*This chapter gives recommendations on the actions the Ministry of VROM can take to strengthen the current and future efforts to reduce the indirect impacts of biofuel production. It is based on the reviews of current quantification, mitigation and monitoring initiatives for indirect impacts as described in chapters 2, 3 and 4, as well as Ecofys' experience and opinion on the topic.*

## 5.1 Quantification of indirect impacts

***We recommend the Ministry of VROM not to undertake their own detailed modelling exercises to quantify the indirect impacts of biofuels. Instead, we recommend VROM to focus on research that enables a better understanding of the key parameters that form an input to these models, such as the dynamics of co-products in feed markets.***

- A lot of work has already been done on quantification of the problem, as shown in chapter 2.
- Although the exact outcomes of this work differ, it can be shown what the main issues and corresponding assumptions are that influence this outcome.
- Improving insight in and understanding of some of these main issues, e.g. the relation between yield and demand and/or price, the relation between food consumption and food prices, will be challenging but is key to reducing the uncertainty in the outcomes.
- Regardless of the exact outcomes, all reviewed work shows that indirect impacts of biofuel production are significant.

## 5.2 Mitigation of indirect impacts

***We recommend the Ministry of VROM to focus most of its efforts on indirect impacts on practical mitigation measures. We thereby recommend to actively contribute to both global and project-level solutions.***

- We recommend not to focus solely on solutions which relate to biofuel production. The actual negative indirect impacts of biofuel production encountered (e.g. deforestation) are partly a consequence of the lack of control mechanism in other sectors such as agriculture.
- Global level solutions are likely to take a very long time to be implemented. We therefore also highly recommend developing policies that encourage project level solutions. This will be crucial in reducing unwanted indirect impacts during the obligation period of the Renewable Energy Directive.

- At the project level a number of options are available that reduce or exterminate the indirect impact of biofuels. The Ministry of VROM can help shape international policy that favours these projects or implement specific support measures if international progress is slow or unsatisfactory. The following options are available at the project level :
    - Use of residues as biofuel feedstock.
        - There is generally a large consensus that this is a viable way to mitigate indirect impacts.
        - However, some residues currently already have a use. In this case indirect displacement effects could still occur. This needs more attention, for example as is happening in the RFA project discussed in section 3.6.
    - Use of algae or other aquatic biomass as feedstock.
        - There is generally a large consensus that this is a viable way to mitigate indirect impacts.
        - However, technology to do so is still very much at the R&D stage and this option is therefore of little relevance for the short term.
    - Use of feedstock from previously 'unused' land without provisioning services.
        - This can be an effective measure, however there is still a debate on how to ensure optimal effectiveness of this measure, see Appendix D.
        - Although the concept of 'unused' land is often discussed, there is a lack of workable definitions. The RCA initiative makes a pragmatic start, see section 3.7.
    - Use of feedstock from land of which the productivity has been increased such that no displacement of current provisioning services occurs.
        - This can be an effective measure; however, definition, implementation and verification still require more work. RFA work and RCA initiative make a pragmatic start, see sections 3.6 and 3.7.
    - Increasing supply chain efficiency through innovation: producing more biofuel from a certain amount of feedstock or agricultural resources.
        - In quite a few cases this is already being undertaken either for financial reasons and/or due to increased attention for biofuel production from residues.
        - It could reduce GHG savings through changes in biofuel production. For example, more fossil fuel input may be needed to increase biofuel production, potentially worsening GHG balance.
        - The potential option of targeting a maximum biofuel yield per hectare should be used with caution. This could for example lead to use of best agricultural lands for biofuels, leading to a larger displacement effect in e.g. the food sector and thus to larger indirect impacts.

## 5.3 Monitoring indirect impacts

***We recommend the Ministry of VROM to actively support (international) efforts to improve the monitoring of impacts caused by agriculture in general (e.g. deforestation) as well as the monitoring of indicators that allow a better understanding of the role of biofuel production in these impacts. However, monitoring indirect impacts of biofuel production is extremely challenging and will always require a certain amount of modelling.***

- Currently, monitoring of the impact of the agriculture in general is hampered by a lack of data. The Ministry of VROM can stimulate structural monitoring of key impacts such as deforestation.
- If VROM wants to identify the indirect impacts of biofuels specifically, we recommend further work to understand what measurable indicators could provide a better insight in the role of biofuel production in the total impacts from agriculture.
- When the Renewable Energy Directive is implemented, the Dutch government will receive sustainability information on all the biofuels supplied under the target. We recommend VROM (if possible with other Member States) to assess this as soon as it becomes available on its value for monitoring the impacts of biofuels.

# 6 Conclusions

This study has four elements regarding the indirect impacts of biofuel production:

1. A review of quantification initiatives of indirect impacts of biofuel production.
2. A review of mitigation initiatives of indirect impacts of biofuel production.
3. A review of monitoring initiatives of indirect impacts of biofuel production.
4. Recommendations to the Ministry of VROM on how to deal with indirect impacts.

On point 1 it can be concluded that the reviewed quantification initiatives provide:

- No information on the magnitude of indirect impacts on biodiversity.
- Limited information on the magnitude of indirect impacts on food consumption.
- A wide range of magnitudes of indirect impacts on the greenhouse gas balance of biofuels through land use changes: 30 to 103 gCO2eq/MJ fuel. This wide range of magnitudes is due to different values for key input assumptions used by the quantification initiatives. Although a wide range of quantitative results is found, all initiatives predict the impact to be significant for the total greenhouse gas balance of biofuels.

On point 2 it can be concluded that the reviewed mitigation initiatives show that:

- Only a small amount of mitigation measures currently exist and that these are all still under development.
- Most of the mitigation measures that are in advanced development solely incorporate an indirect land use change factor in the life cycle analysis of biofuels based on their feedstock, providing no incentive to mitigate indirect impacts at the project level, given a certain feedstock.
- The Responsible Cultivation Area initiative led by Ecofys and the Renewable Fuels Association's initiative are the first to work on pragmatic solutions for feedstock production that has no or a minimised risk of indirect impacts by preventing displacement effects from occurring.

On point 3 it can be concluded that the reviewed monitoring initiatives show that:

- Few initiatives currently exist that try to monitor the direct or indirect impact of biofuels specifically.
- There is a lack of data on the impacts of agriculture in general, e.g. on deforestation.
- It is extremely challenging to link measurable impacts such as deforestation to biofuel production as these impacts occur through market mechanisms that can not be directly measured.
- Some modelling will always be required to link measurable impacts to biofuel production specifically.
- Data availability on biofuels consumed in the EU may improve in the future through information requirements on biofuels in the Renewable Energy Directive.

On point 4, Ecofys recommends the Ministry of VROM to:

- Focus its policy on mitigation options, both long term global solutions that go beyond biofuels, and short term project level solutions specifically targeted at biofuels.
- Not perform its own modelling of indirect effects, but do more research on key model assumptions such as yield developments or the dynamics of biofuel co-products in feed markets.
- Support structural monitoring of the impacts of agriculture in general, and support additional work to understand what measurable indicators provide a better insight in the role of biofuel production in the total impacts (from agriculture).

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# Appendix A Reasons for not including quantitative results of the LEI work in the comparison

As mentioned in section 2.2 and in Table 2 - 3, it has unfortunately not been possible to extract data from the work of LEI that would allow a useful quantitative comparison with the other initiatives. The following characteristics of the work prevented that:

- The additional biofuel demand assumed in the work was not specified in an absolute value, but rather in a percentage of a baseline on which data was not included in the publication.
- The modelling effort included the energy sector as well, additional to agroeconomic sectors. This lead to the effect that the input additional biofuel demand in the EU led to reduced biofuel demand in other regions. The quantitative extent of this effect was not given in absolute values, so the total increase of biofuel demand could not be determined.
- The absolute value of total cropland expansion was not presented in the publication.
- The effect of increased agricultural intensification and reduced demand in other sectors could not be separately quantified in the model. Therefore specifying a division between the different effects was not possible.
- The GHG effects of LUC and ILUC caused by additional biofuel demand was not included in the modelling performed by LEI.

## Appendix B Draft criteria for Responsible Cultivation Areas

*This appendix specifies the draft criteria that have been defined for the Responsible Cultivation Areas (RCAs) introduced in section 3.7.*

**1** Establishment of energy crop plantations maintains or increases High Conservation Values

- No conversion of areas with recognised High Conservation Values[38] on or after January 2008. This includes legally protected areas and areas with recognised global importance for biodiversity.
- No conversion of areas with one or more High Conservation Values[4] on or after January 2008 that are not formally recognised as one of the areas referred to in principle 1.a.

**2** Establishment of energy crop plantations does not lead to significant reductions in carbon stocks

- No conversion of areas that had one of the following statuses in January 2008:
  - i. Continuously forested areas with a canopy cover of more than 30%
  - ii. Peatland
- The carbon payback time for carbon losses resulting from Land Use Change (including above-ground and below-ground carbon stocks), shall not exceed 10 years. To calculate the carbon payback time, the methodology as laid down in the RTFO Technical Guidance shall be used[39].

**3** Establishment of energy crop plantations respects formal and customary land rights

- The formal right to use the land for energy crop cultivation can be demonstrated.
- Both formal and customary land rights (including use rights) must be known. Where potential land conflicts may arise between the energy crop cultivation and formal or customary land rights, viable solutions must have been identified in cooperation with all owners and users of the land.

**4** Establishment of energy crop plantations does not cause unwanted displacement effects

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[38] HCV 4 contains areas that provided basic ecosystem services in critical situations (e.g. areas critical to water catchments). When checking the presence of HCV 4. within the scope of the RCA concept, it has to be checked in addition that the intended energy crop establishment does not cause negative downstream effects (e.g. a regional scarcity of the water supply caused by the competition between the water demand of the plantation and other users).

[39] RFA (2009) - Carbon and Sustainability Reporting within the Renewable Transport Fuel Obligation. Technical Guidance. Version 2.0, March 2009.

- Existing provisioning services are maintained. Where existing provisioning services are displaced, alternatives shall be implemented that comply with all principles for RCAs.
- Establishment of energy crop plantations may not lead to the opening of remote areas with High Conservation values through new infrastructure. Remote areas are areas that are currently not or difficult to access due to the absence of infrastructure.

Notes:

- C1) The High Conservation Values mentioned in criterion 1 refer to the six values identified by the High Conservation Network, see the box shown below. The HCV concept also plays a central role in the methodology as detailed tool-kits have been developed to identify HCVs.
- C2) The carbon payback time is defined as the number of years after which the project has a zero net effect on GHG-emissions. In other words, this is the number of years after which GHG emission savings, resulting from the bioenergy produced by the project, have compensated net losses in carbon stocks.
- C3) It must be demonstrated beyond reasonable doubt that either no competing land claims exist, or where competing land claims existed, that agreements with all owners and users of the land through the principle of free, prior and informed consent has been achieved. This would exclude areas that are of critical cultural importance (HCV 6) or areas that are critical for the livelihoods of local populations for which no good alternatives exist (HCV 5).
- C3) Criterion 3 on land rights does not mean that land to which certain parties claim the ownership or use rights, can not qualify as an RCA. Such land can still qualify as RCA, if HCV values 5 and 6 are respected and fair and equitable agreements on the transfer of land rights can be agreed upon with the free prior and informed consent of all owners/users. As explained above, it is not within the scope of the RCA-concept to finalise such agreements.
- All criteria refer to the site selection as the RCA concept is limited to site selection. For such sites to produce biomass in a sustainable manner, a more elaborate set of sustainability criteria will need to be complied with during actual establishment and production: e.g. on labour conditions, soil, air and water. Such production criteria are defined in initiatives such as the Roundtable on Sustainable Biofuels.

# Appendix C Examples of Responsible Cultivation Areas

*This appendix gives three examples of Responsible Cultivation Areas as discussed in section 3.7. It does not provide discussion on associated criteria and definitions, e.g. the definition of idle or degraded land. For more information on these topics, please refer to section 3.7 and Appendix D.*

**Responsible cultivation areas: example**

**Expanding oil palm production in degraded areas**

- ***Expanding production without ILUC:*** Casson (2007) describes how carbon emissions from the oil palm sector can be reduced by redirecting oil palm expansion away from forested areas and peat lands to degraded lands. Planting Oil Palm on Imperata Grassland could actually lead to an increase in carbon stocks.
- ***Potential:*** Casson (2007) cites numbers on degraded land from the Indonesian Ministry of Forestry, which has classified over 23 million ha as degraded land, of which only a part would be needed to foresee in the growth in palm oil demand. Garrity et al. (1997) estimate the total are of Imperata Grassland in Asia at 35 million ha (8.5 million ha in Indonesia). This compares to roughly 10 million ha of globally harvested oil palm plantations today.
- ***Risks:*** Not all degraded land will be available. Some of it will not be suitable for oil palm production. Furthermore, degradation is often caused by the presence of people and degraded areas are therefore often populated and the local population may be occupying some of the lands. Finally, degraded lands may have already been allocated to other companies who have not realised plantation but may still retain rights to the land.
- ***Economic viability:*** Generally feasible. Some additional costs in the case of Imperata Grassland for herbicides treatment in the early years of establishment. Fairhurst et. al. (2009) find that Oil Palm plantations on grasslands are more profitable than plantations on secondary forest.
- ***Added value from carbon benefits:*** Based on Syahrinudin (2005) and IPCC (2006), Ecofys (2007b) finds that the GHG-performance of biofuel from oil palm can be significantly improved if plantations are established on Imperata Grassland. This could lead to a higher value as mechanisms such as the EU Renewable Energy Directive and EU Fuel Quality Directive reward higher GHG savings

## Increased Efficiency Production Areas: Examples

**Integration of sugarcane and cattle (Sparovek et al 2007)**

- ***Expanding production without ILUC:*** Sparovek et al., (2007) presents an integrated sugarcane and cattle production model in which hydrolysed bagasse is used as animal feed. The additional feed would allow for more cows per hectare, freeing up part of the pasture land for sugarcane. As a result the same land that used to support a certain number of cattle now supports the same amount of cattle while also producing ethanol from sugarcane. In other words, sugarcane production is expanded on pasture areas without displacing the original cattle production. This could reduce the migration of ranchers to remote areas in the Cerrado and the Amazon region.
- ***Potential:*** The authors do not give estimates for the total potential. Not all pasture land will be suitable for sugarcane. Total permanent meadow and pastures, both natural and cultivated, in South America amount to over 450 million ha, with 200 million ha in Brazil (FAO 2009). Total sugarcane area equals 8 million ha (6.7 in Brazil), suggesting a significant potential for the integration model.
- ***Risks:*** The competition between the use of bagasse for animal feed or for heat and electricity generation. In addition, the model requires close interaction between two very different sectors.
- ***Economic viability:*** The authors state that the model is feasible at current market conditions.
- ***Added value from carbon benefits:*** Policies to promote GHG-savings through biofuels in the EU and US are expected to include emissions from ILUC in the near to medium future. Projects that can demonstrate to prevent ILUC, such as the integration model, would then be recognised to achieve higher GHG-savings and may therefore obtain a higher value.

**Integration of soy and cattle (Dros 2004)**

- ***Expanding production without ILUC:*** Dros (2004), describes the so-called Integrated Crop Livestock Zero Tillage system in which soy cultivation is rotated with cattle raising. This crop rotation increases the fertility of the pasture and thereby allows for in increase in the cattle density. As with the above sugarcane integration model, this model prevents ILUC by increasing the productivity of the original land use. This allows for the expansion of soy production onto pasture areas without displacing the original cattle production.
- ***Potential:*** As with the sugarcane expansion model the potential for this model is expected to be large due to the enormous areas used for extensive cattle raising – 450 million ha in South America.
- ***Economic viability:*** Field trials show the model is economically viable
- ***Risks:*** Cultural differences between farmers and ranchers, legal, technical and educational constraints inhibit the 'automatic' adoption of such practices on a large

scale.

- ***Added value from carbon benefits:*** Policies to promote GHG-savings through biofuels in the EU and US are expected to include emissions from ILUC in the near to medium future. Projects that can demonstrate to prevent ILUC, such as the integration model, would then be recognised to achieve higher GHG-savings and may therefore obtain a higher value.

# Appendix D The debate on the effectiveness of expanding on land without provisioning services or 'idle land' and its links to the RCA initiative

*This appendix serves as an extension to the information presented on expanding on land without provisioning services in section 3.7.*

The RCA concept is still under development and pilot projects are under way. Discussions with experts and stakeholders have primarily raised concerns on the effectiveness of using land without current provisioning services. Some parties claim that agricultural land is scarce and will become more scarce in the future and therefore should not be used for biofuels. In other words, while expanding production in these areas may not cause displacement effects today, there may be displacement effects in the future – as the land would otherwise have been taken into production for food in the future.

The validity of this argument depends strongly on the future land requirements for food, feed and fibre production on the one hand and the availability of agricultural land on the other hand. Both are subject to large uncertainties. On the positive side, the doubling in world food production in the past decades was met almost entirely by agricultural intensification, with only 10-15% of the increase in production coming from an expansion in cropland. With a slowdown in population growth, future growth rates in food demand are expected to decline. In terms of land availability, a recent study by IIASA shows that several hundreds of millions of ha of land suitable for rainfed biofuel crop production exist that are not used for cropland today and are not under forest cover or in protected areas. On the negative side, yields may not grow as strong as they did in the past and climate change may have negative impacts. On the large potential land availability found by studies such as (IIASA 2009), large uncertainties exist on what these lands are actually used for today and to what extent these areas can be taken into agricultural production. Further analysis of this topic is beyond the scope of this study.

The coordinators of the initiative state that the solution is primarily meant as an intermediate solution, initially aimed at the period up to 2020/2022 – the period for which the EU and the US have set biofuel mandates, until global efforts to control unwanted direct LUC are effectively implemented, thereby eliminating unwanted indirect LUC, and that the risk of structural land shortages in the medium term is small. In addition, the coordinators state that today's biofuel energy crop feedstocks can switch easily between food and fuel markets and therefore using areas without current provisioning services for biofuels does not pose irreversible risks – the crops and the areas on which they are cultivated could be reverted to food market relatively easily.