An Analysis of iLUC and Biofuels

Regional quantification of climate-relevant land use change and options for combating it

Dr. Uwe Lahl

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Abbreviations

BL	Bushland
CL	Cropland
CO_{2eq}	Carbon dioxide equivalents
CS	Carbon stock
dLUC	Direct land use change
dt	Decitonne = 100 kilogram
RE Directive	EU Directive 2009/28/EC to promote the use of energy produced from renewable sources
FL	Forest land
DG	Directorate General of the EU Commission:
GJ	Gigajoule = 1,000 megajoule; 1 GJ = 280 kWh
GLtemp	Grassland, temperate
GLtrop	Grassland, tropical
ha	Hectare; 1 ha = 10,000 m^2
iLUC	Indirect land use change
LUC	Land use change; LUC = dLUC + iLUC
Mg	Megagram, 1,000 kg, previously "t" for "ton" (metric)
MJ	Megajoule; 1 MJ = 0.28 kWh
NGOs	Non-governmental organisations
OL	Other lands
RFL	Rain forest land
GHG	Greenhouse gas
WL	Wetland
WTW	Well to wheel

1. Executive summary

The reason for this study is the EU Commission's report on the impact of the EU biofuels policy which must be submitted by the end of 2010. To fight climate change, the EU has set its sights on further expanding the use of biomass in its policies – not just for the transport sector. In terms of the effects of EU biofuel policy, the question arises as to whether indirect land use change associated with biofuels should be combated through regulation and, if so, how. Direct land use change brought about by biofuels has already been addressed in the Renewable Energies Directive (2009/28).

This study concludes that land use change (LUC) – or converting natural forest, grazing land or fallow land to cropland – continues to be a major problem in some regions of the world, not only for climate protection. The effects of land use change can be direct (dLUC) or indirect (iLUC). If the original use of the land was carbon-rich in the vegetation or in the soil (for example, forest) and the subsequent use is carbon-poor (pastures or crops), LUC increases the amount of carbon dioxide released and thus adversely affects the climate.

An analysis of previous approaches shows that models that see iLUC as a global effect and define global factors, risk adders etc. to combat iLUC, are not sufficiently sound and produce widely varying results. Thus, using a global approach to determine LUC or dLUC and then subsequently regulating it is also not supported by purely scientific arguments. On the contrary, the study proposes a regional approach to calculating iLUC. The goal is to determine the greenhouse gas emissions of biofuels (GHG) brought about by iLUC in a specific region. A regional approach can be based on the conditions specific to the respective region and the data for this region which is contained in country statistics. This makes the results more resilient. It also appears that LUC is mainly caused locally or regionally. In looking at the problem of iLUC, the major impact of regional trade in relation to the impact of international trade may not be disregarded. If calculation were performed by region, it would still be possible to completely capture the global emissions caused by biofuels associated with LUC by adding together the regional totals.

The emissions caused by all land use change in the region would be determined first for the calculation. To determine the percentage of total regional emissions allocated to a specific type of biofuel, it is assumed that LUC is caused by all agricultural sectors equally and an increase in overall regional agricultural production correlated with LUC both directly and in a linear fashion. If the GHG emissions caused by LUC for a specific type of biofuel in a region are now known, the dLUC included in the RE Directive can now be used to determine the GHG emissions produced by land use change for a specific type of biofuel in the respective region. There are then various options for allocating the iLUC emissions. One option would be to allocate the regional iLUC effect of a type of biofuel at originator level, i.e. to the individual farms in the region. Another option would be to leave allocation of iLUC emissions at regional level. Here, all biofuel products in the entire region can now be ascribed to a uniform regional iLUC effect or the regional iLUC emissions can be shown differentiated by type of biofuel.

The sample calculations in this model differentiate the iLUC effect by type of biofuel in various regions and provide sensitive and reliable results that also capture small-scale iLUC effects. One weakness of the regional calculation model is, in particular, its limited ability to capture cross-border production chains and iLUC effects between countries. Still, the regional model is in principle suitable for capturing the regional iLUC effects and determining a "regional iLUC factor".

The analysis of the political options for combating iLUC shows that a regional approach would have a much more effective controlling effect. A meaningful controlling effect can only arise from regulations that are regionally oriented, i.e. at nation state level. Something else that must be achieved is that countries (society and government) that can provide evidence that they have both successfully and sustainably fought LUC should also be rewarded (and vice-versa). Generally, the iLUC problem can, however, only be solved at the root if the regulations for combating dLUC that currently exist for biofuels in Europe are also extended globally to the other agricultural sectors and global land use change is prevented overall.

Bi- or multi-lateral agreements on biofuels can be reached between the EU and key agricultural countries as an interim solution. Specifically, adding an option to the RE Directive is recommended: the EU Commission should be given the ability to calculate and define a regional iLUC factor for a nation state given defined political conditions. These conditions include, in particular, a documented refusal of the country over the long run to enter into a bilateral agreement with the EU to fight against LUC or iLUC. Overall, a blend of different activities is recommended that combines a medium- to long-term international solution that gets to the root of the problem with short-term interim solutions through "bilateral agreements" supported by a regional iLUC model.

2. Reasons for the study

Climate change currently poses the greatest threat to the planet Earth. To limit its impact and reach the 2-degree target, industrial nations have to reduce their greenhouse gas emissions from 1990 levels by 80% to 85% by the year 2050. The transport sector contributes more than 20% of greenhouse gas emissions in Europe. To lower emissions caused by transport and secure the energy supply for the future, the European Community has set its sights on, among other things, replacing fossil fuels with non-fossil fuels (biofuels). The 2006 EU strategy for biofuels, however, also emphasises the importance of ensuring the sustainability of biofuel production [1]. In the ongoing discussion about which sustainability criteria to apply, various experts [among them from the Federal Government's Advisory Council on Global Environmental Change (WBGU) 2008 [2]] have called for the inclusion of emissions arising from indirect land use change (iLUC[1]). Because they can be considerable in scale and have a massive effect on the product life cycle assessment or the product carbon footprint (PCF) of bioenergy.

In the USA, the Energy Independence and Security Act (EISA) from 2007 defined binding greenhouse gas reduction targets for biofuels across their entire life cycle (at least minus 50%) for the first time and included emissions from indirect land use change [3].

The European Parliament and the Council of the European Union passed the Directive (2009/28/EC) to promote the use of energy produced from renewable sources at the end of April 2009 [4]. This Directive tasks the EU Commission with the following:
"The Commission should develop a concrete methodology to minimise greenhouse gas emissions caused by indirect land use change. To this end, the Commission should analyse, on the basis of best available scientific evidence, in particular, the inclusion of a factor for indirect land use changes in the calculation of greenhouse gas emissions and the need to incentivise sustainable biofuels which minimise the impacts of land use change and improve biofuel sustainability with respect to indirect land use change. In developing that methodology, the Commission should address, inter alia, the potential indirect land use changes resulting from biofuels produced from non-food cellulosic material and from ligno-cellulosic material.
The RE Directive also stipulates [4]: The Commission shall, by 31 December 2010, submit a report to the European Parliament and to the Council reviewing the impact of indirect land use change on greenhouse gas emissions and addressing ways to minimise that impact. The report shall, if appropriate, be accompanied, by a proposal, based on the best available scientific evidence, containing a concrete methodology for emissions from carbon stock changes caused by indirect land use changes, ensuring compliance with this Directive, in particular Article 17(2)."

In the end, the EU Commission should therefore, to the extent that it is feasible, present a legislative proposal for how indirect land use change (iLUC) or land use change (LUC) is to be captured and included in the net calculation of the CO_2 savings by using biofuels over fossil-based fuels.

[1] The following distinction is made in this study: LUC = land use change, dLUC = direct LUC (e.g. Farmer A converts a field for crops to produce biofuels), iLUC = indirect LUC (conversion usually takes place in at least two stages between several farmers and also in some cases between various agricultural products). $\sum$ iLUC + $\sum$ dLUC = $\sum$ LUC

In August 2010, the EU Commission began a hearing on "indirect land use change". The consultation refers to studies commissioned by the Directorate General Energy [5], Climate [6], Agriculture [7] and Trade [8] and, as a core question, asks to what extent the work already conducted consolidates the findings so that it appears possible to integrate a corresponding regulation into biofuel legislation. The Commission also asks which regulatory concepts are considered useful in achieving the set goals.

To address these problems in more detail, the German Biofuels Association (Bundesverband der deutschen Bioethanolwirtschaft – BDB[e]), Berlin, and the Union for the Promotion of Oil and Protein Plants (Union zur Förderung von Oel- und Proteinpflanzen e. V. – UFOP), Berlin, commissioned BZL Kommunikation und Projektsteuerung to assess the various possibilities for capturing indirect land use change (iLUC) within the framework of the EU Directive on renewable energy.

3. Factual background

When **land use change (LUC)** occurs, i.e. the change in the way agricultural land or forests are used or if land is used otherwise, such as for a road or commercial purposes, greenhouse gas emissions increase when the carbon stored in the vegetation and soil is reduced. LUC leads, in particular, to a reduction in the carbon contained in the soil (humus decomposition) when the change in land use decreases the amount of carbon in the aboveground and then ultimately in the under-ground biomass (humus decomposition) due to a change in vegetation (pastures or cropland instead of (primitive) forest). This process leads to a change in the CO_2 equilibrium on this land and then to a release of carbon dioxide which thus negatively affects the climate. It usually takes several years for the biomass decomposition caused by the change in land use to adjust to the new CO_2 equilibrium. This process, however, can also be reversed on degraded soils, e.g. by optimising crop rotation systems with legume decomposition and through the appropriate fertiliser.

A distinction is made between the following land use changes:

- Direct land use change (dLUC)
- Indirect land use change (iLUC)

Indirect land use change can arise, for example, if energy crops are planted on land that used to be used for growing food, animal feed or fibres. In this case, land elsewhere can be, for example, converted to cropland to replace the previous production that has been "displaced" (examples: through clearing virgin forests, using grassland for a different purpose). Because the land use change from carbon-rich land to cropland is not direct but indirect occurring in one or more stage(s), this is referred to as indirect land use change, or iLUC for short.

The international debate about whether it makes sense to grow energy crops is currently shaped to a large extent by the discussion about indirect land use change. One approach is to only include *direct* land use change (dLUC) but not *indirect* land use change (iLUC) because of methodology problems and insufficient data, like the approach used in the PAS 2050: 2008 [9] [2]. These stand in contrast to the mandates given to the EPA by the Energy Independence and Security Act (EISA) 2007 [3] or to the Commission in the Directive 2009/28/EC [4] that require inclusion of iLUC. The US Environmental Protection Agency (EPA) has, in the meantime, already applied corresponding models [10].

4. The iLUC hypothesis - analysis of previous models for capturing and quantifying iLUC

In brief, the iLUC hypothesis is:

Increasing the use of biofuels indirectly results in land use changes and thus in additional greenhouse gas emissions. The use of biofuels does not therefore make a meaningful contribution to climate protection.

The iLUC hypothesis was established on the basis of scientific research conducted over the last few years. On closer examination, the iLUC hypothesis is comprised of three individual theses:

- Thesis 1: Biofuels indirectly result in land use changes.
- Thesis 2: Land use changes lead to more greenhouse gas emissions.
- Thesis 3: Biofuels do not make a meaningful contribution to climate protection.

The current status of scientific knowledge about these three components of iLUC will be examined more closely in the following section. The individual parts of the iLUC hypothesis have to be considered separately because the facts and findings for each are different.

In the last 3 to 4 years, efforts have been made to capture and quantify iLUC in the USA and Europe by a number of working groups found primarily at universities and specialised institutes. The focus of this work was to understand the correlations of Thesis 1 better.

4.1 Thesis 1: Biofuels indirectly result in land use changes.

It is not disputed that displacement happens or can happen among the various agricultural sectors as a result of growing bioenergy crops. This is also concretely reported or

[2] A PAS (Publicly Available Specification) is not a standard, it is only an agreement among the authors which also does not ensure general consensus within society – which is what a standard requires.

unequivocally observed or can be shown using maps [11] in individual regions although allocation to the various agricultural sectors is difficult.

Direct land use change (dLUC), such as converting grassland to cropland to produce raw materials for biofuels, is captured using the existing certification systems set forth by the RE Directive [4] and reflected in the greenhouse gas totals for the respective land.

It is more difficult to capture the indirect impacts. There are different methods used to capture the iLUC effect of biofuels. The IFEU study [12] commissioned by the BDB[e] describes the methods being discussed internationally and analyses their weaknesses. Two different methods are generally used to calculate iLUC at international level:

- Complex econometric models [10, 13, 14, 15]
- Simplified deterministic [3] approaches [16].

All models attempt to capture and quantify the impact at global level.

4.1.1 Econometrical models

The first study on the global indirect land use effects of US ethanol production was published by Searchinger et al. [13] in 2008. The authors used an econometrical agricultural model for their calculations. These types of agricultural models can be used to calculate how price and the agricultural land needed is affected when the demand for raw agricultural materials changes. Searchinger et al. [13] arrived at the conclusion that the iLUC effects of ethanol production in the US, which is based on corn, produces more greenhouse gas emissions overall than the savings achieved over fossil fuels[4].

Other calculations with different econometrical models were then conducted and published. These calculation models include, for instance GTAP (Global Trade Analysis Project) of Purdue University, IMPACT of the IFPRI (International Food Policy Research Institute) and CAPRI (Common Agricultural Policy Regional Impact Analysis) of the University of Bonn. All studies concluded that there is an iLUC effect when biofuel production increases.

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3 lat. determinare. Key calculation dimensions are "determined" in the sense of "defined".

4 Abstract: *Most prior studies have found that substituting biofuels for gasoline will reduce greenhouse gases because biofuels sequester carbon through the growth of the feedstock. These analyses have failed to count the carbon emissions that occur as farmers worldwide respond to higher prices and convert forest and grassland to new cropland to replace the grain (or cropland) diverted to biofuels. By using a worldwide agricultural model to estimate emissions from land use change, we found that corn-based ethanol, instead of producing a 20% savings, nearly doubles greenhouse emissions over 30 years and increases greenhouse gases for 167 years. Biofuels from switchgrass, if grown on US corn lands, increase emissions by 50%. This result raises concerns about large biofuel mandates and highlights the value of using waste products. [13]*

In the last two years, these results were criticised. For example, major differences in results were observed when **different models** were applied to the **same questions**. For example, the iLUC effects fluctuated between 30 and 103 g CO_{2eq}/MJ [17] for comparable biofuels. If one also considers that **fossil fuel** has a greenhouse gas emission of 83.8 g CO_{2eq}/MJ according to the RE Directive (Annex V Section C No. E9), the problem posed by this range of fluctuation becomes evident.
In the USA, the EPA tried to solve this dilemma by choosing a model for regulatory purposes from among the various models which best represented actual conditions according to leading experts. The model experts were asked which model was the best during a hearing. Their responses were in summary:

- None of the models can provide the "right" answer because each of the models has specific strengths and weaknesses. This means that different results will be obtained when the models are applied.
- The models are already too complex to enable transparency.
- The complexity is not yet adequate to incorporate all dependent factors sufficiently [18].

Figure 1 shows the results of another study that compares different econometrical models with one another [19]. The GTAP (Global Trade Analysis Project) and FAPRI (Food and Agriculture Policy and Research Institute) models were used. The iLUC effect that would occur as a result of additional production of 2.6 billion gallons of corn-based ethanol was calculated. The frequency distribution of the results is considerable.

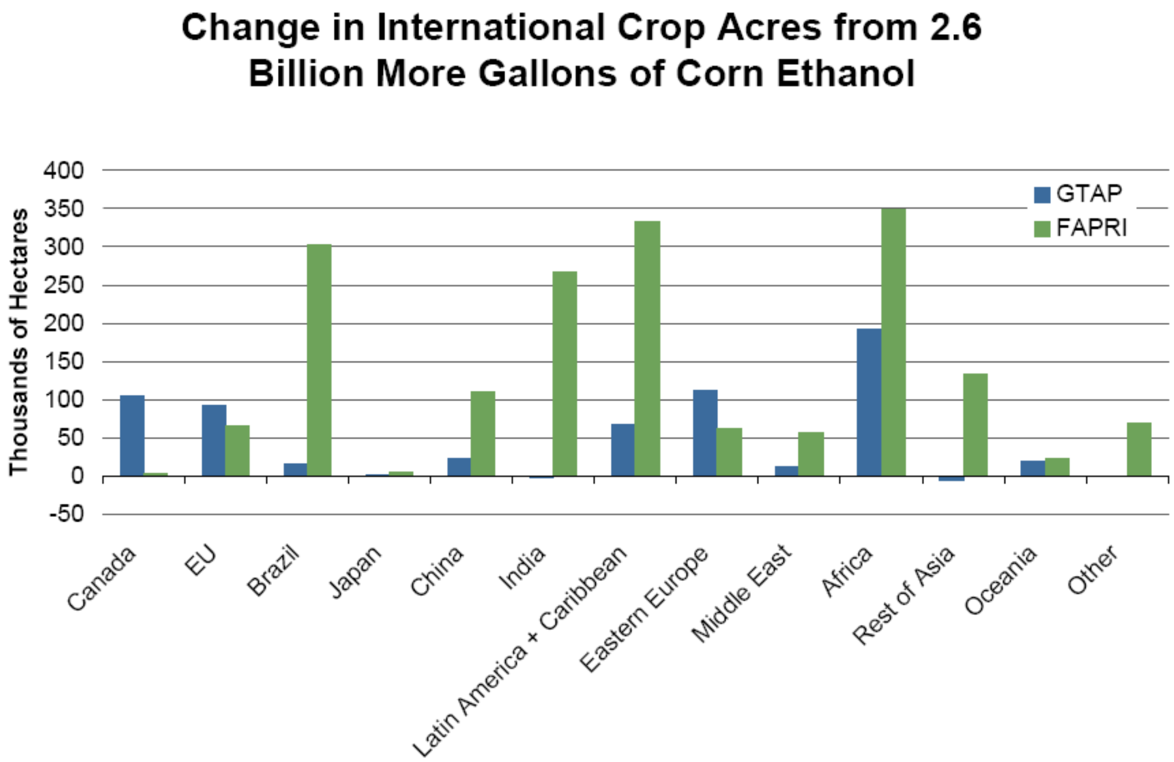

Figure 1: **iLUC effects: comparison of the results of the GTAP and FAPRI models [19]**

A study commissioned by various European NGOs entitled "Biofuels: Indirect land use change and climate impact", also confirmed the wide frequency distribution of the results for various models and methods [20]. As can be seen in Figure 2, the frequency distribution of the results of the models used to calculate iLUC – after the extreme models (Corbey, WBGU, Ensus) are eliminated – at up to around 50 g CO_{2eq} per MJ of biofuel, which coincides well with the results of other studies (approximately [17], see above).

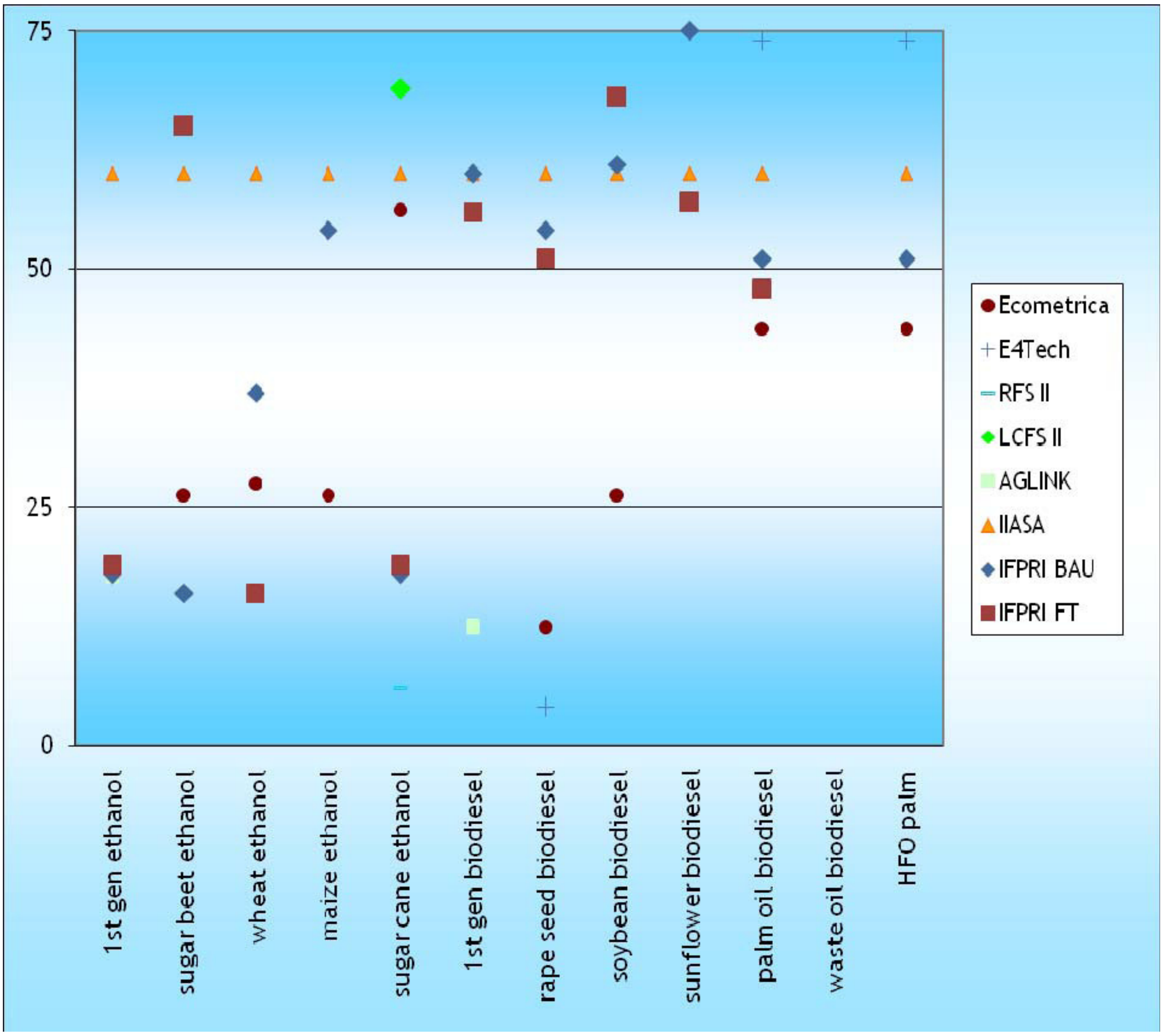

Figure 2: **iLUC factors for biofuels according to various studies [g CO_{2eq}/MJ] [20]**

A current comparison of six more recent studies (four of them from 2010 alone) on the iLUC factor that only looked at biofuels from US corn produced a frequency distribution of results from 14 to 104 for a range of 14 to 200 g CO_{2eq}/MJ (for a 30-year period), see Table 1 [21]. If applied to a 20-year period, the values would have to be further increased by 50%.

Table 1: Published estimates of ILUC emissions induced by expansion of corn ethanol in the US and EU.

All studies are reported with ILUC emissions amortised over 30 years of production for comparison. To normalise any value to 20 years of production, add 50%. (Based on Plevin, O'Hare et al., in review) [21]

Study	Target year	Shock size (10^6 m³)	ILUC factor (g CO_{2eq}/MJ)	Range (g CO_{2eq}/MJ)
Searchinger et al. (2008)	2016	56	104	20–200a
Hertel et al.(2010)	2001b	50	27	15–90c
Dumortier et al.(2009)	2018/19	30	n/a	21–118d
USEPA (2010)	2012	7.5	81	62–104e
	2017	14	58	43–76e
	2022	10	34	25–45e
Al Riffai et al. (2010)	2020f	0.47	36	36–53g
Tyner et al.(2010)	2015	7.6	14	14–18h

a Calculated from reported sensitivity results.
b Based on the GTAP-6 2001 database, adjusted for 10% greater corn yield in 2010.
c Based on a combination of high and low values for various economic model parameters.
d Based on evaluating alternative model assumptions.
e 95% CI around mean considering only the uncertainty in satellite data analysis and carbon accounting.
f Based on the GTAP-7 2004 database, using the model to project out to 2020.
g Effect of additional 10^6 GJ after meeting 5.6% mandate. Higher value is for greater trade liberalisation.
h Based on 2006 data constructed from 2001 GTAP database. Low value includes yield and population growth.

Under the scope of the four analyses initiated by the EU Commission mentioned at the beginning of this study, the existing agricultural models were also used to determine **whether there is an iLUC effect brought about by the biofuel targets adopted by the EU, and, if so, to what extent**. The question also arose as to whether the models are robust enough to use for incorporating the iLUC aspect into the EU's existing biofuel regulation.

Three models – AGLINK-Cosimo, ESIM and CAPRI – were used for calculations in the EU study for the DG Agriculture [7]. These "partial agro-economic equilibrium models" are, according to the authors of the study, robust, scientifically recognised tools for simulating policy changes within the agricultural sector. They can be used to identify the impact of policy on, among other things, supply and demand, trade flows and domestic and global markets. As long as indirect land use change is triggered via the market by price signals [5] in third countries, these can also be captured according to the authors of the study.

[5] See further down about regional constraints for land use change resulting from price signals.

Table 2: iLUC effects calculated using three models [5]

	AGLINK	ESIM	CAPRI
EU			
Production Fuels			
Ethanol	↑↑	↑↑↑↑	↑↑(by assumption)
Biodiesel	↑↑↑	↑	↑↑(by assumption)
Production Feedstocks			
Wheat	↑	↑	↑
Coarse grains/maize	↑(< 1 m t)	↑	↑ (small)
Oilseeds	↑	↑	↑↑
Production livestock products	negligible	↑ (small, pork and poultry only)	cattle numbers slightly ↓
Net trade Fuels			
Ethanol	imports ↑↑↑	imports ↑	
Biodiesel	imports ↑↑↑	exports ↓	
Net trade Feedstocks			
Wheat	exports ↓	exports ↓	imports ↑
Coarse grains/maize	from exporter to small importer	imports ↑	imports ↑
Oilseeds	imports ↓	imports ↑ (small)	imports ↓
Vegetable oils	imports ↑↑	imports ↑	imports ↑↑
Land use: EU	+ 1.44 mn ha (arable) - 1.13 mn ha (pasture)	+ 0.700 mn ha (agricultural area)	arable ↑ fallow ↓ [1] pasture ↓
World Market			
Prices Fuels			
Ethanol	↑ (small)	↑	
Biodiesel	↑↑	↑↑	
Prices Feedstocks			
Ethanol feedstocks	ca. zero	↑ (wheat),↑↑ (maize)	↑ (cereals)
Biodiesel feedstocks	ca. zero (oilseeds) ↑ (oils)	↑ ↑ ↑ (oils)	↑ (oilseeds) ↑ (oils)
Global land use (cereals, oilseeds, sugar)	+ 5.2 mn ha (+ 0.7%)		

1. Total agricultural area fixed by assumption

Table 2 shows the considerable differences in the results produced by the models. This is explained in detail in the study and the reason lies in the strengths and weaknesses of the respective models. The conclusion is nevertheless that none of the models used can adequately predict the possible iLUC effects of the EU biofuel policy for 2020.

In the EU study commissioned by the Directorate General Climate [6], the six most well-known agricultural models were applied to four EU scenarios with exact specifications. Figure 3 shows a selection of the most important results.

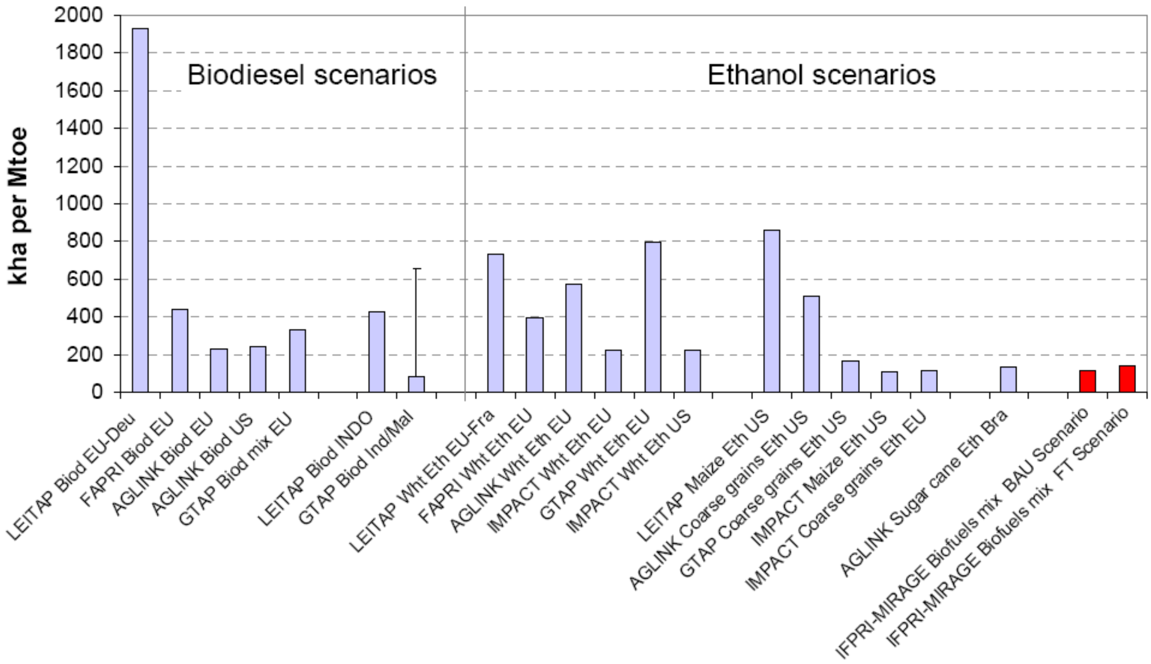

Figure 3: iLUC effect determined using various agricultural models [6]

In all models, it was found that iLUC increased when the demand for biofuels in Europe increased. However, this analysis also showed that the results are subject to extreme fluctuations.

A computable global equilibrium (CGE) model is only used in one of the four EU studies, namely in the one commissioned by the GD Trade [8] to predict the impact of EU biofuel policy, in this case an extensively modified version of the existing MIRAGE model. The model simulations showed that EU biofuel policy only has a very limited effect on food prices, with a maximum change in price for the food sector of +0.5% in Brazil and +0.14% in Europe. The analysis of the effects of biofuel demand on iLUC shows that ethanol and, particularly ethanol produced from sugar cane, generate the highest net greenhouse gas savings. Biodiesel made from palm oil remains as efficient as rapeseed oil even if the emissions from converting bogs in Indonesia/Malaysia are taken into account. The model also shows that the iLUC emission coefficients can increase when biofuel quotas further increase in Europe.

In the in-house review commissioned by the DG Energy [5] the key weaknesses of the model calculations conducted up to now are shown to verify and predict iLUC associated with biofuels. The results were obtained through a critical analysis of the relevant scientific literature in the last few years.

The most important results:

- The basic data for globally available agricultural land entered in the models varies considerably. The fluctuations range from 1.2 up to 2.0 billion hectares for the year 2000. There is no consensus in the scientific community about the correct figure. The use of empirical data is often weak or insufficient [22].
- If the **harvest yields per area** grew faster due to the increased demand for biofuels, less land would be necessary. From a theoretical standpoint, it is likely that this effect will occur (because price increases, particularly in developing and emerging nations, bring money to farmers and thus make investments possible). However, this probable relationship is difficult to quantify empirically. Previous agricultural models assumed that the effect could be disregarded or was zero. Newer work includes this effect but not sufficiently. Sensitivity analyses show, however, that this effect can be highly relevant for the results. With higher assumed harvest yields in response, the iLUC effect can be lowered by 27% to 80%.
- The amount of agricultural land has been shrinking in the EU for many years. An increase in demand for biofuel would change this trend. This effect has not been included in the previous studies.
- Growing raw materials for biofuels is generally associated with the occurrence of co-products that are used, for example, in animal feed and thus replace land for growing animal feed. Studies indicate that this positive iLUC effect resulting from animal feed production can be between 8 and 64% (average 36%) for the biofuel policy overall and between 35 and 94% for individual crops such as corn, sugar cane, wheat and rapeseed. Extremely different figures for the co-products and diverging substitution effects were assumed in the studies analysed. This has a major impact on the respective results.
- The adopted EU legislation and its impact on land use were not included anywhere in the studies analysed. In addition, in none of the forecast calculations was a land use policy assumed that, for example, gave higher priority to nature conservation.
- If the expansion of agricultural land resulting from higher demand for agricultural products is easy to model in a linear model (in mathematical terms), there are major differences in the question of to the detriment of which land this expansion occurs. It is almost impossible to predict to what extent the expansion of croplands occurs at the expense of forest or grassland.
- Most models did not include the land use change where wetlands or peatland was converted. This means that the effects are underestimated.
- What are known as "multi causal" LUC or iLUC effects were not included in most of the studies. This effect is particularly significant in tropical rain forests where "illegal logging" is one of the causes or even one of the primary drivers of land use changes.

- In several studies, no distinction is made among the different types of biofuel (ethanol, soybean oil diesel, palm oil diesel, etc.) in the analysis. The result is extreme generalisations. Other studies show that the results for the different types of biofuels are very different. A distinction is also not usually made between the iLUC effects per region or country. Only in one study was it determined which iLUC results occur depending on the type of biofuel and region. It is evident that the regional effect is very pronounced (see also Chapter 5).

Overall, the authors found that the results for the projected impact of land use change caused by biofuels have decreased over time probably due to the methodological refinement of the calculation models. While the original work by Searchinger et al. [13] found that the greenhouse gas impacts of biofuels associated with iLUC were twice that of the emissions caused by the consumption of fossil fuels, three of the four most recent studies on biofuels showed net greenhouse gas savings over fossil fuels even when the iLUC effects were included according to the authors of the in-house review commissioned by the DG Energy [5].

4.1.2 Deterministic models

In deterministic models, the key global calculation parameters are "determined". This means that no results are calculated using mathematical models but determinations made that are intended to represent reality as best as possible. The models use simple assumptions and calculate results in just a few steps. As a result, they are much more transparent than the highly complex econometrical models.

A study is currently being conducted for the UK Department for Transport to develop this type of model [23]. Another deterministic model was developed on behalf of the German Environmental Ministry. In the first version of the model in 2008, what is called a "risk adder" was defined to be added to biofuels as a penalty. To derive the model [16] the initial question is what form land use change resulting from a displacement process can take in the worst case. Because the displacement effects are primarily assumed to be global in this model, all countries that participate as exporters in world trade are affected. The potential CO_2 emissions from iLUC are determined in a simplified fashion as a mean value of the percentage of land for agricultural exports broken down by global region and the respective C released as a result of land use change there (see Table 3 according to [24])

Table 3: Derivation of the potential CO_2 emissions caused by iLUC according to Fritsche, cited in [12] according to Institute for Applied Ecology (Öko-Institut)/IFEU 2009 [24]

Region, culture vs. type of land	Assumptions about C from dLUC (acc. to IPCC) [Mg CO_2/ha]	Cultivated land in the "global mix" Simplified percentages	Land-weighted proportional GHG emission for LUC [Mg CO_2/ha]
EU, rapeseed/wheat vs. grassland	254	20%	51
USA, corn vs. grassland	254	25%	64
Brazil, sugar cane vs. savanna	491	50%	246
Indonesia, palm oil vs. rain forest	972	5%	49
Total (rounded off)			400
Per year, for 20 a [Mg CO_2/(ha*a)]			20

Arising from these determinations is an emissions potential of 410, i.e. around 400 Mg CO_2/ha, that produces a theoretical iLUC value of 20 Mg CO_2/(ha*a) when distributed over 20 years as set forth in the RE Directive.

Because the use of fallow land or an increase in yield in the production of bioenergy sources does not always result in indirect land use change, the authors of the model define a "conservative minimum" of 25% of the theoretical iLUC value above, which corresponds to 5 Mg CO_2/(ha*a).

These emissions now have to be allocated to the cultivated biofuels in this version of the model. To do this, the specific biomass yields per hectare and the conversion rates of biomass to biofuel are used. The co-products are allocated using the energy content method set forth in the RE Directive. In the end "risk adders" for different biofuels are calculated using this data. Table 4 provides several results of this calculation [25]. According to the results, rapeseed from the EU has the highest iLUC values while diesel made from palm oil the lowest.

A term was changed in a later form of the model (2010) [26]. The result of the calculation is no longer called a "risk adder" but an "iLUC factor".[6]

Table 4: Sample derivation of iLUC factors according to the Fritsche's proposal (2007, 2009) taking into account land yield values and allocation values according to Fehrenbach et al. (2007) [25]

Region, culture	Land needed m²/GJ biomass[a)] (primary and co-products)	Allocation percentage for biofuel[a)] primary product	iLUC value[b)] g CO_2/MJ
EU, rapeseed	200	60%	60
EU, wheat	174	55%	48
USA, corn	131	55%	36
Brazil, sugar cane	121	88%	53
Indonesia, palm oil	79	48%	15

[a)] Figures from Fehrenbach et al. (2007) – not identical to the calculation basis of RE Dir. Annex V
[b)] Offset with 5 Mg CO_{2eq}/ha (25% of 20 Mg CO_{2eq}/ha)

The main calculation process remains the same.[7] Refinements in the data used produce a modified result of 13.5 Mg CO_2/(ha*a) for the theoretical iLUC value. In addition, the calculated iLUC value is also set at 25% in this refined model and produces an iLUC factor of **34 g CO_2/MJ** using the typical global average net yield of 100 GJ of biofuels per ha.

Unlike the first version of the model, a distinction is no longer made in the types and kinds of biofuels in the new version (see Table 4). Instead, the same global iLUC factor is used for all biofuels.

4.1.3 Analysis and assessment of the models

Providing evidence of the extent and significance of the iLUC effect is difficult in principle because the percentage of bioenergy production in global agricultural production is almost non-existent – if wood production is removed from the equation. In addition, the volume of biofuels traded globally is another order of magnitude *below* that of bioenergy products. Overall, even a drastic increase in bioenergy would not *on average* bring about any *significant* changes in the global system.

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6 The "iLUC factor" created here is not a factor in a mathematical sense but should be seen as an "addition" that is added to the greenhouse gas balance of a biofuel.

7 *To translate the iLUC factor to a given biofuel, the land-based values given above (t CO_2/ha/year) need to be divided by the fuel-specific yield ($GJ_{biofuel}$/ha/year), resulting in energy-specific emission factors (g $CO_2/MJ_{biofuel}$).*

What the studies achieve is to apply calculation models that allocate the impacts of a change in global demand in individual agricultural sectors, even if comparatively small, to changes in price and also, if applicable, a corresponding increase in the need for agricultural land. If, in one model, the increase in sectoral demand for an agricultural product is mathematically associated with a price increase and this in turn is linked to a proportionally linear incremental increase in the agricultural area, the application of this model to the EU biofuel strategy results in an iLUC effect, as the studies show. This kind of result, however, should not be confused with quantifying the real iLUC effect even if an iLUC value is ultimately produced by the calculation. Instead, the model produces a result arising from the mathematical relationships defined by the creator of the model. In practice, however, the increased demand can also be met using fallow land or by intensifying use of existing agricultural land. This would be the best case scenario for climate protection: an increase in biofuel production without an iLUC effect. Further developed models attempt to incorporate these effects. But the results above show that the authors give extremely different weighting to the different options for action open to the actors in the agricultural sectors.

Why is quantification so difficult? The difficulty becomes clear if the global iLUC phenomenon is described in vivid terms. Here is the definition that appeared in a current study of the Institute for Applied Ecology (Öko-Institut) [16]:
*"In that view, cultivating biomass feedstocks can have **indirect** LUC (ILUC) effects through displacing current agricultural (food, feed) or forest (fiber, timber) production to **other** areas - e.g. grasslands or forested land – which causes **dLUC there**. As the displacement could move previous agricultural production to areas outside of a country, could occur with significant time lags, and could be distributed through global trading, ILUC **cannot** be determined with respect to any individual feedstock production activity – it is "non-local".*

*The non-locality of indirect effects is a result of the non-locality of global commodity markets – unless one assumes a **full** global "tracing and tracking" for the origin of all traded commodities, one **cannot know** whether a production increase of an agricultural commodity such as wheat (and possibly a respective conversion of previously unused land) in a given country is "caused" by a rise in demand for bread in another country, or by a change in trade relations, or by a rising demand for bioethanol produced from wheat somewhere else. Even if the feedstock into the ethanol plant would be "traced back" to its source(s), only full global tracing could reveal any implications this feedstock demand has on all other production – and not only for wheat, but also for interrelated feedstocks such as maize (corn) or rye which have a functional equivalent to wheat on the different markets and uses."*

This definition gives an idea of the complexity a model would have to have to represent this effect. Because in the definition above iLUC is supposed to be a global phenomenon shown by means of international agricultural trade, it can also only be captured using global models. However, a credible way to quantify iLUC has not yet been found as shown above. The results of the model calculations are widely dispersed and produce extremely different results even when the exact same facts are entered. The explanations provided for this can only be confirmed. No one has performed inaccurate calculations or developed poor models. The structure of the models and the assumptions that the models are based on are different and thus produce different results.

Is it possible, asked in the most simple terms, to develop a "right" or "best" model and then apply it to the biofuel sector? As shown above, the scientists who developed the models do not agree on how to select a model. Letting politicians choose a model upon which to base policy is problematic. And finally, articles have also been published over the last few months that express general scepticism about whether quantification can even be successful *at all*. One of the first scientists who pointed out the significance of iLUC recently said:
"All models suffer from the uncertainty about whether past economic relationships will hold true in the future." [27]

This leads to the crucial question: are we actually on the right track scientifically with the application of the global models? Or is the above phenomenon of the iLUC hypothesis at global level too complex to develop models which would make consistent and precise predictions possible seen in terms of today’s possibilities [28]? In addition to this model-theoretical question, other arguments need to be weighed that also address the problem of the global orientation of the iLUC analysis to date.

4.2 Thesis 2: Land use changes lead to more greenhouse gas emissions

This part of the iLUC hypothesis is much more tangible than the first part. In principle, it is not disputed, for example, that converting forests to cropland results in a loss of the carbon stored in the vegetation and in the soil because it eventually makes its way to the atmosphere as carbon dioxide, a greenhouse gas. An international consensus has also been successfully reached on which carbon stocks are to be assumed for which land or land uses. Corresponding estimates and default values have been compiled in the annex of this study for illustration purposes.

Of course, some values may be different than those above for specific areas. But in these cases as well, there are internationally agreed methods for how to determine the carbon stocks [29]. In practice, the carbon stocks for calculating the greenhouse gas emissions brought about by iLUC are determined by inconsistently relying on the conventions and the existing pool of data. For instance, in the studies described at the beginning, differences in the basic data used were identified from a factor of 2 to 15 [5]. This observation, however, is only evidence that the data selection needs to be improved but does not represent a fundamental problem in determining the greenhouse gas effect arising from land use changes.

If the changes in land use are known or can be determined for a given region, e.g. for a country, the greenhouse effect can be calculated on this basis with adequate scientific reliability.

The conclusion is that the second thesis of the iLUC hypothesis is substantiated and can be quantified with sufficient accuracy.

4.3 Thesis 3: Biofuels do not make a meaningful contribution to climate protection

The greenhouse gas emissions caused by iLUC and those that are incurred during the production of biofuel together produce the total greenhouse gas emissions of each biofuel analysed. In the last sub-step of the iLUC hypothesis, this result is compared to the greenhouse gas emissions assumed from the use of an equivalent energy unit of a conventional fuel (petrol or diesel). If the difference between the biofuel and the conventional fuel is negligible or even negative (biofuel results in higher emissions than conventional fuel), the biofuel does not make a contribution to climate protection. This third sub-step of the iLUC hypothesis cannot be objected to methodologically speaking.

On the one hand, how high the global iLUC effect actually is cannot currently be quantified. On the other hand, the comparison carried out in many of the studies on the iLUC hypothesis was insufficient. Because just as it would be necessary to calculate the indirect effects on the biofuel side, the same would have to be done for petroleum or conventional fuel. This is illustrated in a comparison carried out by Coleman [30], see Figure 4.

The issue of "unconventional oil" is one of the key indirect effects on the conventional fuel side. Unconventional petroleum includes, for example, bitumen or crude oil from tar sand, extra heavy oil and pyrolysis oil or crude oil from oil shale. In addition, synthetic fuels from natural gas (GtL) and coal (CtL) are considered unconventional fuels in this context. In summary, it can be said that unconventional fossil fuels make up approx. 5% of total global oil production [31]. These unconventional fuels are associated with considerably higher greenhouse gas emissions than conventional petroleum because of their more complex production process (by a factor of up to 2.5). Figure 5 shows the greenhouse gas emissions associated with fuels from different types of petroleum.

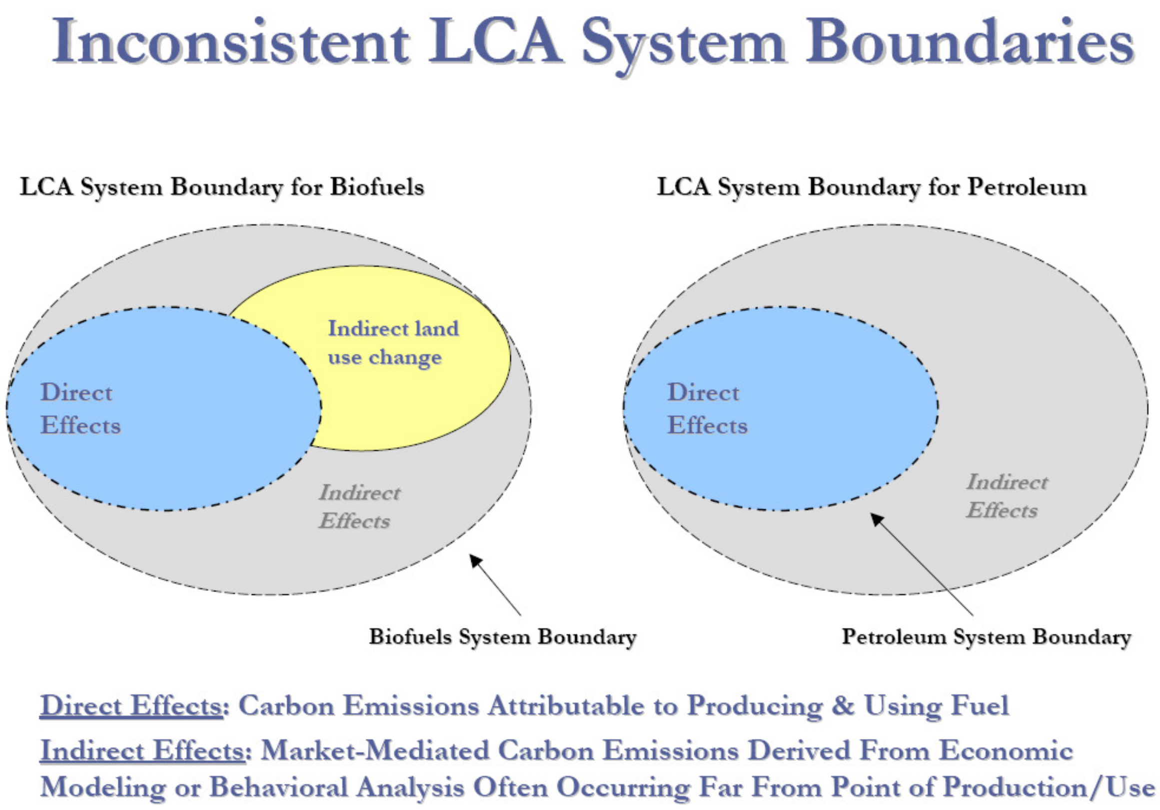

Figure 4: Comparison of the system boundaries for fuels [30]

If the increasing percentage of oil and deep-sea oil were included in the calculation of greenhouse gas emissions for conventional fuels, this value would have to be set 10 to 20% higher [31]. In addition, it would have to be analysed *which* petroleum would be displaced by an increase in the percentage of biofuels in a concrete comparison between biofuels and conventional fuels. **Here, there are some indications that support the argument that biofuels slow down expansion into the area of unconventional oil and thus the reference values should be looked for here and not in the area of an oil mix spanning all types of sources.**

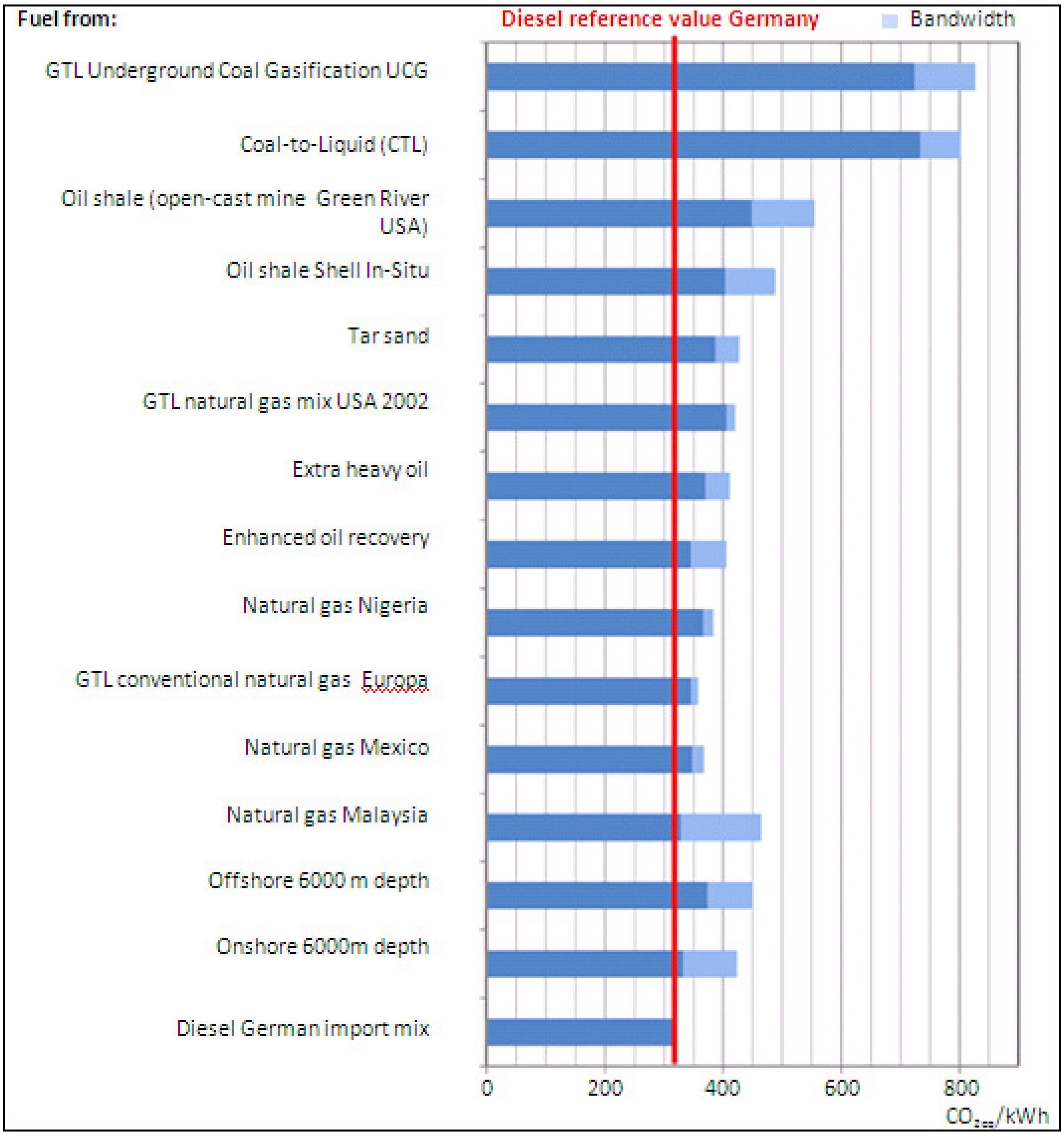

Figure 5: Greenhouse gas emissions for fossil fuels (WTW[8]) [31]

The overall climate assessment of natural gas and the fuels made from it would also have to include disruptions and large-scale accidents like the recent explosion of the "Deepwater Horizon" oil platform and the widespread pollution of the **Gulf of Mexico** (GoM) and its coastal areas triggered as a result including the containment efforts and cleanup activities. Table 5 shows an estimate of the indirect impact of the consequences of this accident [32].

[8] Well to wheel: assessment of the energy requirement and greenhouse gas emissions starting with the initial fuel (well) up through the use of the fuel in the vehicle in the driving cycle (wheel)

Table 5: Indirect carbon intensity increase associated with Gulf Of Mexico CH_4 release, 100% gasoline allocation case [32]

Barrels per day of crude assumed released	60,000
Barrels of crude per ton of crude oil @ API gravity of 33	7.33
Tons of crude oil per day from GoM (Gulf of Mexico)	8,186
Methane release as% of mass of crude release *(per BP estimate)*	40%
GoM tons of methane per day	3,274
Days since start of spill, as of 15 July 2010	*86*
BCF (billion cubic feet) of methane as of July 15, 2010 GOM	4.9
CO_2-equivalent tons indirectly added per day, million metric tons	2.36
CA share of GoM methane emissions	10%
Daily gasoline demand, CA RFG (Re-formulated Gasoline), millions	43.8
CA RFG Btus (British Thermal Units)* per gallon	113,300
MJ per gallon of RFG2	124.8
Daily RFG MJs of demand in CA, billions	5.5
g CO_{2e}/MJ of CA RFG added by GOM release – 20 year GWP	3.9
g CO_{2e}/MJ of CA RFG added by GOM release – 100 year GWP	1.4

*Thermal value (1 BTU = 252 calories)

The conclusion about the third part of the iLUC hypothesis is thus that there is no basic methodological difficulty in comparing the greenhouse gas totals for a biofuel and for conventional fuels. However, the conclusion reached in many studies that biofuels do not make a positive contribution to greenhouse gas emissions is unjustified. On the one hand, the scientific quantification of the iLUC effect at the global level has not yet been successfully established beyond a doubt (see above). **On the other hand, the indirect effects have not generally been included to date (or not sufficiently) in calculating the greenhouse gas totals for conventional fuels.** It can also not be denied that there are also several methodological shortcomings as well as problems with data in the field of indirect effects for fuel production from petroleum and there is thus a need for further research.

4.4 Alternatives to calculating the iLUC effect

The iLUC hypothesis that biofuels are counterproductive to climate protection because of the indirect land use change they induce *cannot* be considered backed up by these studies. This is also not the same as denying that there might be an iLUC effect caused by bioenergy or biofuels. On the contrary, this study assumes that there is an effect. The many individual cases that can be seen at regional level alone are proof. However, quantifying this effect with global models has not been successful so far.

What alternatives then exist to capture and quantify iLUC? The data that exists at regional level in the individual nation states is generally better than at global level. In addition, the land use change that has actually taken place in the regions can be used as a starting point and the effect does not have to be calculated with complex models. The effect has already occurred at regional level (or not if there are laws to prevent this) and can be captured in data and allocated. But can these real figures be successfully aggregated into a regional model?

None of the models assessed above can project how the relevant regions or countries that produce biofuels for the global market will position themselves politically with respect to iLUC in the near future. If nothing else because the models generally are globally oriented and regional effects are not captured at all or only marginally. However, a decisive factor in the significance of iLUC in the future will be how the individual governments decide to combat iLUC (see below).

Deterministic models can also not offer a better solution to the problems described for capturing and quantifying the iLUC effect. Proof is provided by the example of the Institute for Applied Ecology (Öko-Institut) model presented in this study. Essentially, a global average agricultural hectare which is comprised of the current global trade quantities of raw materials[9] and their respective carbon stocks[10] is calculated with a lot of effort in this very simplified model. If an additional quantity of biofuels were now to be ordered on the global market, a corresponding quantity of land would be needed according to this model. This change in the balance would then be compensated for by iLUC in these countries. Because, however, it cannot be assumed that the effect is 1 to 1 (almost 100%) because there is, for example, the possibility of increasing yield (see above), 25% or 50% is used for the calculation. While the models shown above try to capture the iLUC effect using, in some

[9] Here, trade with animal products and domestic trade are disregarded which results in an incomplete picture.

[10] The methodology is subject to criticism because, for example, the carbon stocks of the available cropland are used for agricultural raw materials such as corn or grain while the changes in carbon stocks as a result of land use change are used for soybean or palm oil (cropland resulting from the conversion of savannas or tropical rain forests).

cases, very complex mathematical agricultural models, this approach simply defines (deterministic approach) the effect to be 25% (or 50%) of a global calculation factor.

Dale [33], for instance, criticises the previous analyses for one-sidedly favouring the production of animal feed which doesn't make much sense in terms of sustainability.[11] The percentage that agriculture contributed to the total greenhouse gas emissions produced by human beings in 2005 was approximately 14%. As calculations of the Potsdam Institute for Climate Impact Research (PIK) show, greenhouse gas emissions would considerably increase by the year 2055 if the per capita consumption of food remained qualitatively and quantitatively the same as in the year 1995. If an increase in the consumption of meat and dairy products as a result of rising income were included, emissions would also increase more. If the demand for meat and dairy products dropped by one-quarter every 10 years between 2015 and 2055, emissions would, in contrast, fall to a level below that of 1995 [34].

Some scientific publications see past land use change (deforestation) at regional level as linked to economic development and industrialisation although this development often comes to a standstill when the respective national economy reaches a certain stage in its development. In some cases, development can even be reversed (net increase in forests) [35]. Statistics also show that land use change was not usually only caused by an expansion in agricultural use, see Table 6 [36]. However, there are also negative examples from the past with respect to deforestation of entire regions.
Crucial is that the changes brought about by the economic, cultural, social and political conditions **in the respective country** are defined (see Table 7 [37]) – and are not heavily shaped by global agricultural markets and their economic stimuli [38].

This means that the key to understanding the iLUC effects should not be looked for in global econometrical or even deterministic agricultural models but rather in the respective decisions and decision-making structures in the regions or countries. From the author's point of view, this is the key shortcoming of the iLUC discussion today. The countries with their populations and their governments are outside of the model analyses and are not seen as active political units but more as objects exposed to the global agricultural markets with no will of their own.

[11] "5. Analysis unfairly favours animal feed production from land vs. biofuel production. 6. Animal feed production is "sustainable" but biofuel production is not – this is intellectually bankrupt."

Table 6: Frequency of broad clusters of proximate causes in tropical deforestation [36] – Important: cumulative values in the "cum (%)" column.

	All cases (n = 152)			Asia (n = 55)		Africa (n = 19)		Latin America (n = 78)	
	abs	rel (%)	cum (%)	abs	rel (%)	abs	rel (%)	abs	rel (%)
Single-factor causation									
Agricultural expansion	6	4	4	2	4	1	5	3	4
Wood extraction	2	1	5	0	–	2	11	0	–
Infrastructure expansion	1	1	6	0	–	0	–	1	1
Other[a]	0	–	–	0	–	0	–	0	–
Two-factor causation									
Agro-wood[b]	22	15	20	12	22	2	11	8	10
Agro-infra[c]	30	20	40	3	6	2	11	25	32
Agro-other	5	3	43	1	2	3	16	1	1
Wood-infra	1	1	44	0	–	0	–	1	1
Wood-other	1	1	45	0	–	1	6	0	–
Three-factor causation									
Agro-wood-infra	38	25	70	21	38	2	11	15	19
Agro-wood-other	6	4	74	4	7	1	5	1	1
Agro-infra-other	8	5	79	0	–	0	–	8	10
Wood-infra-other	1	1	80	0	–	0	–	1	1
Four-factor causation									
All	31	20	100	12	22	5	26	14	18
Total	152	100	–	55	100	19	100	78	100

Table 7: Driving forces of tropical deforestation by scale of influence [37]

	% of all cases					
Scales	All factors (range) (n=152 cases)	Demo-graphic factors* (n=93)	Economic factors (n=123)	Technological factors (n=107)	Policy and institutional factors (n=119)	Cultural or socio-political factors (n=101)
Local	2 – 88	88.2	2.4	23.4	4.2	15.8
National	1 – 14	1.3	13.9	2.6	2.1	7.4
Global	0 – 1	0.0	1.4	0.0	0.0	0.0
Several scales: global to local interplays	11 – 94	10.5	82.3	74.0	93.7	76.8

* 6 cases of 'population pressure' (unspecified) could not be attributed to scales. Source: Own data; see Geist & Lambin (2001).

5. Developing a regional model for calculating iLUC

iLUC should not be captured and quantified globally but regionally. This is underscored by an entire range of findings and arguments.

5.1 The most important arguments in favour of a regional approach

Many of the arguments that favour a regional approach have already been dealt with in the literature.

5.1.1 Increasing yields vs. LUC

In the studies conducted by Mueller and Copenhaver for the US state of Illinois, it was shown that even in a country like the USA with its very high level of yield worldwide, it was possible to completely satisfy the increase in demand for biofuels that occurred over the last few years with a further increase in yield. An iLUC effect did therefore not occur in Illinois. Instead, the rise in demand was met and, at the same time, the export quantities even further increased [39]. This result underscores how important the decisions taken by regional actors can be. For more information, see the results from Lambin & Geist in Table 7 on page 28.

The regional possibility of **increasing agricultural production by means of higher harvest yields** is important particularly in developing and emerging economies. A significant increase in yield could be achieved with relatively little money. And these regional differences are clearly evident in reality. We can point out positive and negative examples in countries on all continents.

5.1.2 Domestic developments

A regional iLUC effect can have completely concrete forms and actors. Leaseholder A is displaced from his grazing land due to an increase in domestic demand for bioenergy and looks for new land for his cattle, converting savanna or forest for this purpose. This causality does not have a relevant link to international market activities. The rise demand for bioenergy domestically is more often the result of political decisions in that country [40]. If the analysis is extended to other agricultural sectors that, when increased, result in iLUC, this correlation becomes even more evident. An increase in domestic meat consumption, for example, can also lead to iLUC. This effect would, however, also be primarily domestic. If, for example, incomes change in a region and food consumption as a result (more meat and dairy products, China), the higher demand is primarily met by more production domestically, particularly in traditional agricultural countries. These developments first and primarily change the regional agricultural structures before the global markets are affected because the rise in demand or increased purchasing power initially sends signals directly and immediately to the regional markets [41]. This means that more meat consumption first strengthens a *regional* market for meat. The consequence may be shifts in land use, in some cases also dLUC or iLUC.

5.1.3 Importance of domestic trade

It must be assumed that domestic trade plays a particularly important role in large agricultural countries. The quantities of goods traded internationally are only 10 to 15% of the quantities actually produced depending on the agricultural product. According to Fritsche et al. [1613], in 2006 only 14% of the global production of industrial wood and forestry products was accounted for by industrial trade, for agricultural products this figure was 13% and it was as low as 1% for bioenergy sources. It can thus be concluded, as shown above, that the flows of trade within nation states have to be included in the analysis of the iLUC problem because they are more significant than global trade in terms of quantity. This also applies to biofuels with one exception: palm oil from Indonesia/Malaysia because palm oil is primarily produced for export and not for domestic consumption in these countries [42].

5.1.4 No "free" global agricultural trade

It also needs to be kept in mind that globally oriented calculations of iLUC are problematic because international agricultural markets in particular are not free of government regulation. There is no completely free global trade. Regions and nation states have taken very different decisions to protect their regional markets from global markets by way of import duties, subsidies or bans on exports or imports. This does not just vary from region to region but also constantly changes as a result of political decisions. Examples are the ban on exports of rice in Vietnam in 2008 or the current decisions in Russia to ban exports of grain. **Occasionally, trends on global agricultural markets change due to financial speculation activities.** The agricultural price increases, for example, in 2006/2008 were incorrectly attributed to biofuels [43]. Schäfer [41] reports that the physical global production of soybeans is "turned over" around 20 times a year and even 54 times in intercontinental trade using the stock exchange figures from the CBOT (Chicago Board of Trade).

5.1.5 Strategic and political decisions in the regions

The **strategic decisions** of regional actors also need to be accounted for. For example, in Argentina, "land buyers and leasers" became more active far in advance of global market developments solely on the basis of political decisions announced in the USA and Europe. These activities can subsequently lead to LUC or iLUC but can only be identified regionally. In this context, it is also necessary to mention the strategic decisions made by individual governments to purchase or lease land in developing or emerging countries. These factors which are important for regional events in individual countries should not be captured with economic models because they do not follow an economic but a **political logic**. The head of Future Analysis at the Bundeswehr Transformation Centre (Zentrum für Transfomation der

Bundeswehr) warns of intensified struggles for land as a strategic resource in his PEAK OIL study published in July 2010 [44]: "The expansion of agricultural land is also being accelerated by globally operating governments and companies who are today already purchasing or leasing land around the world. These strategic activities in the agricultural sector are likely to expand whereby it is difficult to keep the interests of the private sector and the government or even sub-government separate in the acquisition of land and property."

Figure 6: International land leasing [44]

Why it is more in line with objectives to determine iLUC using regional figures and conditions can be clearly seen using the example of Brazil. Figure 7 compares the regional development of bioethanol production and the clearance of rain forests in Brazil [45].

First, Figure 7 makes it clear that the absolute figures for rain forest losses are still much too high despite the slight drop in deforestation activities. The figure does **not**, however, show that there is an inevitable correlation between rain forest deforestation and ethanol production. The increase in ethanol production did not lead to an increase in rain forest clearance, instead the trends go in the opposite direction. Conversely, this indicates that there must have been other country-specific factors that resulted in rain forest loss **despite an increase in production** and a slight drop in iLUC. Because the curves between LUC and biofuel production are different for other countries in the same time period. In these countries, in fact, there was not less rain forest cleared but more and agricultural production increased. The positive country-specific effects in Brazil (reduction in rain forest losses) could therefore be attributed to political intervention to improve protection of the rain forest, as one hypotheses goes. The hope is that this trend is sustainable. But even if the Brazilian government failed to reach its goal of improving rain forest protection, this would remain a failure of the government to shape policy and would thus be a regional effect (and not a non-political "stroke of fate" in the global agricultural sector).

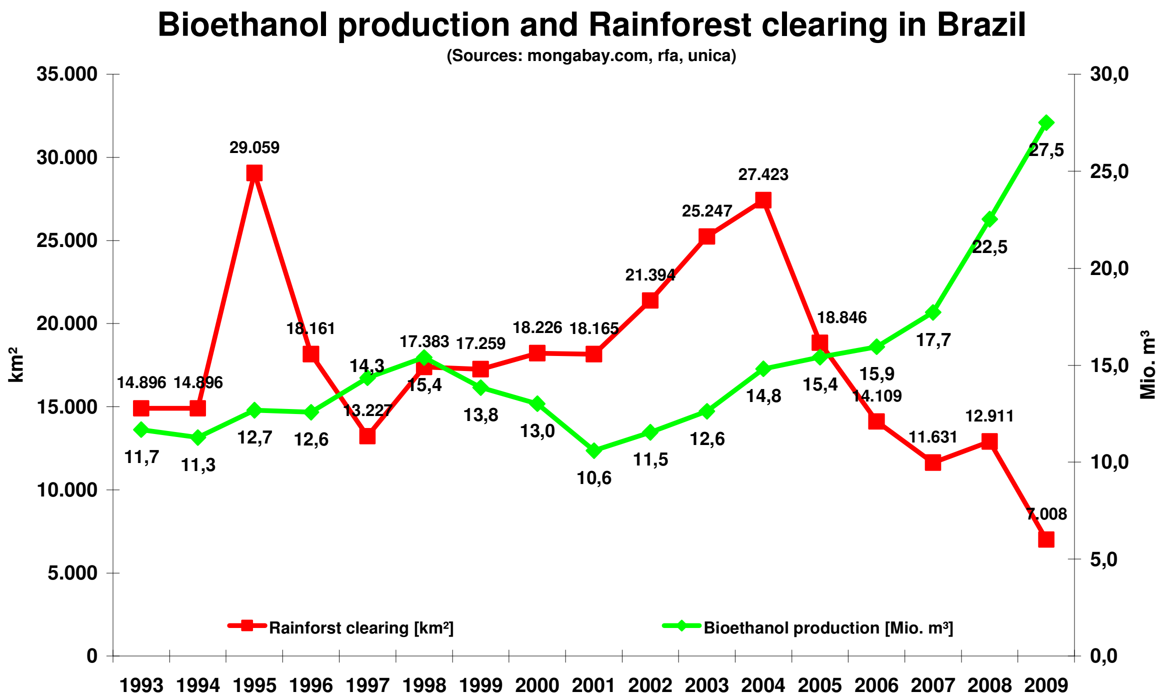

Figure 7: **Bioethanol production and rain forest deforestation in Brazil [45]**

5.2 Features of a regional model

There are many arguments that support a regional approach but how can it be calculated? There are different possibilities for capturing and calculating regional conditions for complex agricultural production and LUC. One possible option is presented in the following section. The goal of the calculation is to determine the greenhouse gas emissions that would be produced in **one region** through iLUC due to production of a specific biofuel.

The greenhouse gas emissions of the production and use of fuels should be determined as follows in accordance with the EU Directive on renewable energies currently in force and the EU Fuels Directive [4, 46]:

Formula 1

$$\mathbf{E = e_{ec} + e_l + e_p + e_{td} + e_u - e_{sca} - e_{ccs} - e_{ccr} - e_{ee}}$$

where:

E total emissions from the use of the fuel [g CO_{2eq}/MJ]

e_{ec} emissions from the extraction or cultivation of raw materials

e_l **annualised emissions from carbon stock changes caused by land use change**

e_p emissions from processing

e_{td} emissions from transport and distribution

e_u emissions from the fuel in use

e_{sca} emission savings from soil carbon accumulation via improved agricultural management

e_{ccs} emission savings from carbon capture and geological storage

e_{ccr} emission savings from carbon capture and replacement

e_{ee} emission savings from excess electricity from cogeneration

e_l represents direct land use change caused by the production of the biofuel in this case.

Formula 1 means that there could/will be figures available in the future for the key biofuel export countries on the annual dLUC. Indirect effects are not contained in the formula above. If iLUC is to be incorporated into the RE or Biofuels Directive, this can occur by including another factor in the formula above (here as a regional iLUC factor).

The calculation for the model presented here is carried out in five steps:

- Step 1 – Calculation of LUC
- Step 2 – Calculation of the CO_2 emissions caused by LUC
- Step 3 – Calculation of the percentage the biofuel sector contributes to the CO_2 emissions caused by LUC
- Step 4 – Calculation of the CO_2 emission of the biofuel sector caused by iLUC
- Step 5 – Options for allocating the iLUC emissions

5.2.1 Step 1 – Calculation of LUC

First, it is determined to what extent land use change has occurred for a review period (year) for a region (nation state[12]). What actually happened in the past (e.g. last year or the year before last) in terms of land use change and agricultural production is used in the calculation. These figures are generally available even if the accuracy of the figures sometimes leaves something to be desired. The land use changes at regional level have to

[12] There are also other feasible options for structuring the regional approach. iLUC can, for example, be used for interlinked markets like the EU or the conditions can be determined separately for various provinces within a large nation state.

be determined for all relevant LUC types separately, i.e. how many hectares of rain forest were converted to cropland, how many hectares of savanna to cropland, etc. Formula 2 illustrates the calculation.

Formula 2

$$\mathbf{LUC^R = LUC^R_{RFL/CL} + LUC^R_{FL/CL} + LUC^R_{BL/CL} + LUC^R_{FL/WL} + LUC^R_{RFL/GLtrop} + LUC^R_{FL/GLtemp} + LUC^R_{GLtrop/CL} + LUC^R_{OLn/OLn+1}}$$

where:

R	Regional
RFL	Rain forest land
FL	Forest land
BL	Bushland
CL	Cropland
GLtrop	Grassland, tropical
GLtemp	Grassland, temperate
WL	Wetland
OL	Other lands

5.2.2 Step 2 – Calculation of the CO2 emissions caused by LUC

Based on these individual contributions to LUC each in ha, a loss or increase in carbon can be determined by means of calculating the respective carbon stock (CS) in the vegetation and in the soil before and after the land use change (see also Chapter 4.2). Generally, it is assumed that there is a loss of carbon for these calculations. This can be expressed by means of a stoichiometry factor in CO_2 emissions. The result of the calculation would thus capture the CO_2 emissions $\mathbf{E^R_{Luc}}$ due to land use changes that took place in the region in the review period. These emissions are then distributed over a 20-year period according to the RE Directive.

Formula 3

$$\mathbf{E^R_{Luc} = [LUC^R_{RFL/CL} \bullet (\mathit{CS_{RFL} - CS_{CL}}) + LUC^R_{FL/CL} \bullet (\mathit{CS_{FL} - CS_{CL}}) + LUC^R_{BL/CL} \bullet (\mathit{CS_{BL} - CS_{CL}}) + LUC^R_{FL/WL} \bullet (\mathit{CS_{FL} - CS_{WL}}) + LUC^R_{RFL/GLtrop} \bullet (\mathit{CS_{RFL} - CS_{GLtrop}}) + LUC^R_{FL/GLtemp} \bullet (\mathit{CS_{FL} - CS_{GLtemp}}) + LUC^R_{GLtrop/CL} \bullet (\mathit{CS_{GLtrop} - CS_{CL}}) + LUC^R_{OLn/OLn+1} \bullet (\mathit{CS_{OLn} - CS_{OLn+1}})] \bullet 3{,}664/20}$$

5.2.3 Step 3 – Calculation of the percentage the biofuel sector contributes to the CO2 emissions caused by LUC

In the third calculation step, it is determined what percentage of these emissions is to be allocated to the types of biofuels being investigated from this total emission caused by LUC ($\mathbf{E^R_{Luc}}$). It is assumed that LUC overall is caused by all agricultural sectors equally and that the intensity of LUC correlates with the increase in agricultural production in a direct and linear fashion. Under this certainly simplified but **conservative assumption** which still generally provides the best picture of the actual processes, the percentage of emissions caused by increased production of biofuels can now be determined. It is calculated from the ratio of the increase in biofuel production to agricultural production overall. The production increase Δ **Agr** is calculated in "Mg grain units"[13]. It is calculated based on the following formula from the relevant production sectors:

Formula 4

$$\Delta \mathbf{Agr^R} = \Delta \mathbf{Agr^R_{food}} + \Delta \mathbf{Agr^R_{feed}} + \Delta \mathbf{Agr^R_{x1fuel}} + \Delta \mathbf{Agr^R_{x2fuel}} \ldots + \Delta \mathbf{Agr^R_{xnfuel}} + \Delta \mathbf{Agr^R_{energy}} + \Delta \mathbf{Agr^R_{chemistry}} + \Delta \mathbf{Agr^R_{others}}$$

where:

R	Regional
chemistry	Chemical sector
energy	Energy sector
feed	Animal feed sector
food	Food sector
fuel	Biofuels sector
x1fuel	Biofuel type x, where 1 could be e.g. ethanol from sugar cane and 2 biodiesel from soybean oil. The total of all biofuels produced through agriculture is $\mathbf{Agr^R_{fuel}}$.

Based on the quotients from e.g. Δ $\mathbf{Agr^R_{x1fuel}}$ caused by Δ $\mathbf{Agr^R}$, $\mathbf{E^R_{LUC}}$ can now be used to determine the emission $\mathbf{E^R_{LUC,\ x1fuel}}$ that is allocated back to the respective biofuel x1.
The product from the quotients mentioned and the emission for total agricultural production is then the $\mathbf{CO_{2eq}}$ emission assigned to the biofuel sector.

[13] "The grain unit is a factor defined for plant and animal products. It describes the capacity of plant products to supply energy in relation to the capacity calculated for feed barley. The animal products are not evaluated by their own energy content but on the net energy content need on average to produce."

Formula 5

$$E^{R}_{LUC,\ x1fuel} = E^{R}_{LUC} \bullet \frac{\Delta\ Agr^{R}_{x1fuel}}{\Delta\ Agr^{R}}$$

5.2.4 Step 4 – Calculation of the CO2 emission of the biofuel sector caused by iLUC

In the fourth calculation step, the total emissions brought about by land use change associated with biofuel x1 is subtracted from the percentage of direct emissions (dLUC) entered for the respective country in the review period as set forth in the RE Directive (see above). The result is then the percentage of emissions that were caused indirectly by biofuel x1 in the region.

Formula 6

$$E^{R}_{iLUC,\ x1fuel} = E^{R}_{Luc,\ x1fuel} - E^{R}_{dLUC,\ x1fuel}$$

5.2.5 Step 5 – Options for allocating the iLUC emissions

In step 5, the calculated emission is assigned to an "originator". There are, however, various options for doing this. Because the model does not provide compelling reasons for which option should be selected, the most important options are described in the following sections. The options should be selected based on regulatory aspects (see below).

a) Allocation at originator level

The calculated emission $E^{R}_{iLUC,\ x1fuel}$ can be assigned to each individual farm in the region in the amount that it contributed to the iLUC effect through an increase in production. To be able to perform this type of allocation, reliable agricultural statistics have to be available which is the case for many but not all relevant agricultural countries. The advantage of this allocation is that there would be a direct controlling effect at individual farm level. The model could also be designed in such a way that only those actors who had achieved their production increase by expanding land use would be assigned a corresponding iLUC factor. Those who had increased production through intensifying land use would be factored out. This would certainly be a desirable controlling effect.

Finally, this type of allocation would create a motivation to prevent or combat iLUC overall for the actors at farm level. However, an individual actor cannot himself do much on his own

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Barley was chosen as a reference value: 1 dt (decitonne = 100 kg) barley = 1 dt grain unit. 1 dt corn = 1.10 dt GU, 1 dt rapeseed seeds = 2.46 dt GU, 1 dt whole milk = 0.86 dt GU 1 dt eggs = 2.57 dt GU, 1 dt pig = 3.50 dt GU, 1 dt dairy cow = 6.70 dt GU. http://www.tll.de/ainfo/pdf/ge_schl.pdf to positively influence the complex events in the region for land conversion. To achieve this, sub-variants of this model could be considered. For example, a type of emissions trading scheme would be conceivable which would allow the individual farm to expand land use and make a contribution to fighting iLUC. One disadvantage of this type of allocation at individual farm level would be the amount of administrative work required.

b) Allocation at regional level

It would take less effort to allocate the emissions caused by iLUC to the biofuels produced in the region overall in the review period. The drawback is that this would not have an individual controlling effect. The actors at individual farm level, however, would develop an interest in the government managing the problem so that regional iLUC values are kept low and there are thus no disadvantages for the export of biofuels to Europe.
This means that, if allocation also takes place at regional level, the controlling effect would primarily be achieved through the decision-making level in the respective nation state, i.e. essentially through the governments.

There are many sub-variants of this type of across-the-board allocation to the biofuel products of the entire region. They are only mentioned here in brief.

No differentiation by biofuel type
From an administrative perspective, it would be easiest to eliminate the differentiation by biofuel type and calculate a regional iLUC factor for all biofuels in the region. The disadvantage here, however, would be that some of the controlling effect would be lost because the various biofuels in the regions have unique characteristics when it comes to land use and iLUC.

Differentiation by biofuel type
If the differentiation by biofuel type were retained, the calculated emission could then be allocated for the biofuel produced in the region overall for the review period. The disadvantage of this proposal is that the calculated iLUC emissions for biofuels that were traditionally produced in the region on a large scale would be distributed to a large volume of fuel which would produce specific emissions values that were too low. If a new type of biofuel (type of plant) were to be grown for the first time in a region and if there were a large increase in production in this period, the iLUC factor would be particularly high in this case. Despite this disadvantage, the advantage would be greater market transparency because all actors can be motivated to effectively combat iLUC.

The allocation effects described could be reduced if allocation were not made to the *produced* quantities of biofuels but to the production *increases*. However, the disadvantage of this proposal is that it would be difficult to assign this iLUC factor to individual batches on the market.

5.2.6 Selecting an option

One of the options described is selected and calculated from start to finish in the following section. This is necessary to carry out model calculations further down and test the suitability of the model. We will first examine the option **Allocation at regional level** and the sub-variant **Allocation to the produced quantities of biofuel differentiated by biofuel type**.

In the key export countries for biofuels, it is usually the case that several different types of plants are grown for biofuels. There is thus no across-the-board value calculated for all biofuels produced in the region but a distinction made among the biofuels according to the raw material used. This doesn't just improve the validity of the data obtained; it also appears necessary because the markets for, e.g. oil crops or sugar cane/grain develop differently.

To develop this option, an additional factor would thus have to be introduced in Formula 1 – the calculation of the greenhouse gas emissions consistent with the EU Directives. It is represented by $\mathbf{e^{r}_{iLUC,\ x1fuel}}$ in the following section which is designed to express that this is a **regional** iLUC factor. The factor is thus calculated for a region, for example, for a nation state or for the relevant actors in a nation state (see Chapter **5.2.5**). It represents the greenhouse gas emissions in g CO_{2eq}/MJ due to iLUC that were caused by the respective **biofuel type x** (in this case x1).

The emission calculated in Step 4 ($\mathbf{E^{R}_{iLUC,\ x1fuel}}$) is divided by the respective quantity of biofuel $\mathbf{Agr^{R}_{x1fuel}}$ produced in the review period in MJ. This results in a regional iLUC factor $\mathbf{e^{r}_{iLUC,\ x1fuel}}$ for biofuel x1. In parallel, an iLUC factor for biofuel x2 and the other biofuels can also be calculated based on the country statistics.

Formula 7

$$\mathbf{e^{R}_{iLUC,\ xfuel}} = \frac{\mathbf{E^{R}_{iLUC,\ xfuel}}}{\mathbf{Agr^{R}_{xfuel}}} \bullet \mathbf{CF_{CP}}$$

The problem of the co-products can be captured in Formula 7 by multiplying with a correction factor $\mathbf{CF_{CP}}$, see Table 8. Here, for example, the use of co-products as cattle feed is visibly positive because iLUC is reduced as a result (reduction in the amount of land needed to grow feed).

The calculation process can be programmed with a spreadsheet calculation program (e.g. EXCEL, OpenCalc) and then used for different data entries (countries, years, biofuel types).

Table 8: Correction factors CF_{CP} for Agr^{R}_{xfuel} due to the occurrence of co-products used in agriculture[14]

Crop feedstock	Co-product percentage [47]	Biofuel produced	Correction factor [1] CF_{CP}
Soybean	83%	Biodiesel	0.17
Sunflowers	60%	Biodiesel	0.40
Rape seed	57%	Biodiesel	0.43
Corn	30%	Bioethanol	0.70
Palm oil	2%	Biodiesel	0.98
n.n.	0%	n.n.	1.00

[1] Assumption: 100% use of the co-product in agriculture; for more information, see also [48]

Supplementing the "international" iLUC effect

In the model shown, iLUC relates solely to regional agriculture. dLUC effects brought about by global agricultural trade are represented by a supplementary calculation.

$\mathbf{E^{R}_{Luc}}$ from Formula 3 captures all emissions that arise in a country in a specific period as a result of direct and indirect land use change. The total of all regional emissions is thus equivalent to the global emission. The overall total is complete, there are no emissions that are not captured as long as, of course, the regional figures were accurate. The latter, however, is not an argument that calls into question the basic completeness of the global total.

Formula 8

$$\sum \mathbf{E^{R}_{Luc}} = \mathbf{E^{glo}_{Luc}}$$

Global agricultural trade has thus an effect at the level of the total emissions in the region. This effect is completely captured, however, in the model developed here.

A concrete example illustrates this point: if, in the US, corn production were used more intensively for producing biofuels, this would create a demand for corn on the global market for, e.g. food or animal feed. This demand could increase production in other countries and, in turn, lead to LUC/iLUC. This effect would not be allocated to the US agricultural production in our model but to agricultural production in the country that responds to the shift in the US market on the global market. This iLUC effect would be completely captured in the region that permits LUC in the model and could be allocated to agricultural products. In keeping with the "originator" principle, it appears accurate to capture this effect not in the US but in the region that allows LUC and to penalise it if appropriate.

In a regulatory situation **that only captures the biofuel sector and not the other sectors** (see below), the model, however, would have a shortcoming in the case described above. The shortcoming becomes apparent if the analysis is differentiated by individual agricultural products such as grains for bread or bioethanol. Here, shifts between the agricultural products and or sectors can occur. Even if the overall total is complete, it is possible that Sector A has to have higher iLUC values and Sector B lower ones in our model as a result of global agricultural trade. The shifts can go in both directions depending on the combination of specific factors. These shifts between the sectors can undervalue or overvalue the biofuel sector, as long as it is the only sector regulated, depending on the case. One could argue here that the **influence of the global agricultural trade is minor because domestic trade is of greater significance. This may be true in many cases** but not always. A review of the specific case is therefore recommended using control questions and, if necessary, the calculation should be supplemented.

A supplementary term that captures the additional iLUC effects caused by international trade with biofuels in the region can be introduced to Formula 7 for this purpose. This term is then, however, only calculated if – as described – it can be shown that this additional effect actually has certain relevance for biofuels for the region during the review period after performing the review using defined control questions (see below).

The first question is whether imports have dropped. Then the export situation is reviewed. If $\Delta\,\mathbf{Agr}^{R}_{im} < 0$ in the affected country in the review period and the absolute amount of agricultural imports bought is greater or equal to the amount (absolute) of the increase in agricultural exports, i.e.

$$|\Delta\,\mathbf{Agr}_{im}| \geq |\Delta\,\mathbf{Agr}_{ex}|,$$

a special review of the influence of the global market on the biofuels sector is necessary and then an international iLUC effect added to the regional iLUC effect on this basis if the concrete calculation produces a relevant additional effect.

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[14] The factors have been taken from the literature. They were not calculated according to the thermal value but through substitution which appears to make sense for the calculation above. The factors can be slightly different for various regions.

The international effect can then assume a maximum level if all land use change not caused by the increase in biofuel production in one's own country was completely caused by shortages of imports due to the additional production of biofuels in other countries.

The RE Directive of the EU is primarily geared toward countries with high biofuel exports to Europe. Without exception these countries are, if examined individually, large agricultural nations whose economies are heavily shaped by the agricultural sector. Imports play a less important role in these countries. Hence the driver of iLUC in these countries is generally exports. And the pressure to expand agricultural land as a result is generated, carried out and implemented "internal to the region" and is usually completely captured using the model developed here even for the individual agricultural sectors. But because the goal stated above is always to completely capture the emissions from iLUC for the biofuels sector, this also has to be captured in individual cases where a transnational effect occurs.

5.3 Application of the model to sample cases (for regional allocation, see above)

In the following section, we have intentionally not performed a calculation for a specific country but analysed various model regions. Various sample cases of land use change are played out from start to finish to examine the respective impacts on the overall result in a sensitivity analysis.

The percentage of dLUC is assumed to be 30% across-the-board for this calculation because the amount is not relevant for the sensitivity analyses performed here. The carbon stocks in the land were calculated conservatively (Annex A). Table 9 according to [49] shows that the land use change assumed in the following section is not unrealistically high.

Table 9: Countries with the highest forest losses globally [49]

Country	LUC, 1995 – 2007 in million ha/a	LUC, forest losses 1995 – 2001% / a	LUC, forest losses 2001 – 2007% / a
Brazil	- 2.9	-0.55%	-0.65%
Indonesia	- 1.9	-1.84%	-2.07%
Sudan	- 0.6	-0.82%	-0.86%
Burma	- 0.5	-1.31%	-1.43%
Zambia	- 0.4	-0.98%	-1.04%
Tanzania	- 0.4	-1.08%	-1.04%
Nigeria	- 0.4	-2.94%	-3.56%
Congo	- 0.4	-0.36%	-0.24%
Zimbabwe	- 0.3	-1.59%	-1.75%
Mexico	- 0.3	-0.50%	-0.40%
Venezuela	- 0.3	-0.58%	-0.60%

Bolivia	- 0.3	-0.45%	-0.46%
Australia	- 0.2	-0.18%	-0.12%

5.3.1 Sample Case A - Medium-size tropical country/palm oil

Sample Case A describes a medium-size tropical country that extracts palm oil and is active in protecting against rain forest clearance to varying degrees (variant A1 to A4) . These activities are clearly evident in the iLUC results (controlling effect of the model: very good).

Table 10: Sample Case A: Medium-size tropical country/palm oil

Case A	Medium-size country, 30% tropical forest	Relevant input figures (GE = grain unit)			ILUC in g CO_{2eq}/MJ
A 1	Palm oil diesel fuel: In the reference year rainforest is converted at today's common level of 0.5% for the production of agricultural product x, which was previously grown on other land. Biofuel industry is a key driver for this development.	LUC^R	=	75 000 ha	**37**
		CS^{RF}	=	265 Mg C	
		CS^{Sa}	=	130 Mg C	
		Δ Agr	=	8 million Mg GE	
		Δ Agr_{fuel}	=	3.5 million Mg GE	
		$Agr_{fuel, energy}$	=	3.05 E+11 MJ	
A 2	Palm oil diesel fuel: In the reference year rainforest is converted at today's common level of 0.05% for the production of agricultural product x, which was previously grown on other land. Biofuel industry is a key driver for this development.	LUC^R	=	7 500 ha	**3.7**
		CS^{RF}	=	265 Mg C	
		CS^{Sa}	=	130 Mg C	
		Δ Agr	=	8 million Mg GE	
		Δ Agr_{fuel}	=	3.5 million Mg GE	
		$Agr_{fuel, energy}$	=	3.05 E+11 MJ	
A 3	Palm oil diesel fuel: In the reference year rainforest is converted at today's common level of 0.01% for the production of agricultural product x, which was previously grown on other land. Biofuel industry is a key driver for this development.	LUC^R	=	1 500 ha	**0.7**
		CS^{RF}	=	265 Mg C	
		CS^{Sa}	=	130 Mg C	
		Δ Agr	=	8 million Mg GE	
		Δ Agr_{fuel}	=	3.5 million Mg GE	
		$Agr_{fuel, energy}$	=	3.05 E+11 MJ	
A 4	Palm oil diesel fuel: In the reference year rainforest is converted at today's common level of 0.1% for the production of agricultural product x, which was	LUC^R	=	15 000 ha	**0.4**
		CS^{RF}	=	265 Mg C	
		CS^{Sa}	=	130 Mg C	
		Δ Agr	=	8 million Mg GE	
		Δ Agr_{fuel}	=	0.1 million Mg GE	

	previously grown on other land. Biofuels industry shows much less increase, as it is not the key driver of this development.	$Agr_{fuel, energy}$ = 1.57 E+11 MJ	

5.3.2 Sample Case B – Large tropical country/soybeans & sugar cane

Table 11: Sample Case B – Large tropical country, soybeans & sugar cane

Case B	Large tropical country, 35% of the land is tropical forest	Relevant input figures (GE = grain unit)			ILUC in g CO_{2eq}/MJ
B 1	Worst case bioethanol: In the reference year 0.17% of rainforest is converted. Livestock farming is replaced by sugar cane cultivation. Bioethanol production is a major reason for this.	LUC^R	=	714 000 ha	**159**
		CS^{RF}	=	265 Mg C	
		CS^{GLtrop}	=	75 Mg C	
		Δ Agr	=	150 million Mg GE	
		Δ Agr_{fuel}	=	29 million Mg GE	
		$Agr_{fuel, energy}$	=	4.23 E+11 MJ	
B 2	Bioethanol: In the reference year 0.17% of rainforest is converted. Livestock farming is replaced by sugar cane cultivation. Bioethanol production is not a major reason for this.	LUC^R	=	714 000 ha	**22**
		CS^{RF}	=	265 Mg C	
		CS^{GLtrop}	=	75 Mg C	
		Δ Agr	=	150 million Mg GE	
		Δ Agr_{fuel}	=	3.5 million Mg GE	
		$Agr_{fuel, energy}$	=	3.76 E+11 MJ	
B 3	Soybean oil diesel fuel: In the reference year 0.17% rainforest is converted to grassland. Pasture is replaced by soybean cultivation. Soybean oil-diesel shows no big increase.	LUC^R	=	714 000 ha	**44**
		CS^{RF}	=	265 Mg C	
		CS^{GLtrop}	=	75 Mg C	
		Δ Agr	=	150 million Mg GE	
		Δ Agr_{fuel}	=	3.1 million Mg GE	
		$Agr_{fuel, energy}$	=	2.81 E+10 MJ	
B 4	Soybean oil diesel fuel: In the reference year 0.17% rainforest is converted to grassland. Pasture is replaced by soybean cultivation. Soybean oil-diesel shows a large increase.	LUC^R	=	714 000 ha	**39**
		CS^{RF}	=	265 Mg C	
		CS^{GLtrop}	=	75 Mg C	
		Δ Agr	=	150 million Mg GE	
		Δ Agr_{fuel}	=	78 million Mg GE	
		$Agr_{fuel, energy}$	=	7.98 E+11 MJ	
B 5	Worst case soybean oil diesel fuel: In the reference year 0.60% rainforest is converted to grassland. Pasture is replaced by	LUC^R	=	2 520 000 ha	**136**
		CS^{RF}	=	265 Mg C	
		CS^{Sa}	=	75 Mg C	
		Δ Agr	=	150 million Mg GE	

	soybean cultivation. Soybean oil-diesel shows a large increase.	Δ Agr_{fuel}	=	78 million Mg GE	
		$Agr_{fuel, energy}$	=	7.98 E+11 MJ	

Sample Case B describes the conditions in a large tropical country which grows soybeans and sugar cane for biofuel production. The standard land use changes today are assumed in Variants B1 to B5 (see Table 9). The regional iLUC results in Table 11 are very high. In Europe, biofuels from this country would not have much chance on the market without more activities to protect the rain forest.

5.3.3 Sample Case C – Country in a temperate climate zone/grain & rapeseed

The calculation model makes it possible to determine the iLUC for various types of biofuels.

Table 12: Sample Case C – Country in a temperate climate zone/grain & rapeseed

Case C	Country in temperate climate zone	Relevant input figures (GE = grain unit)			ILUC in g CO_{2eq}/MJ
C 1	Bioethanol: 0.01% of the forest is converted to the benefit of arable land. Grain farming has a share in producing bioethanol.	LUC^R	=	1 000 ha	1.8
		CS^F	=	130 Mg C	
		CS^{Cl}	=	45 Mg C	
		Δ Agr	=	3 million Mg GE	
		Δ Agr_{fuel}	=	0.6 million Mg GE	
		$Agr_{fuel, energy}$	=	1.71 E+10 MJ	
C 2	Bioethanol: Low percentage of land is converted from grassland to arable land. Grain farming has a share in producing bioethanol.	LUC^R	=	1 000 ha	0.5
		CS^F	=	70 Mg C	
		CS^{Cl}	=	45 Mg C	
		Δ Agr	=	3 million Mg GE	
		Δ Agr_{fuel}	=	0.6 million Mg GE	
		$Agr_{fuel, energy}$	=	1.71 E+10 MJ	
C 3	Bioethanol: Higher percentage of land is converted from grassland to arable land. Grain farming has a share in producing bioethanol.	LUC^R	=	25 000 ha	13.0
		CS^F	=	70 Mg C	
		CS^{Cl}	=	45 Mg C	
		Δ Agr	=	3 million Mg GE	
		Δ Agr_{fuel}	=	0.6 million Mg GE	
		$Agr_{fuel, energy}$	=	1.71 E+10 MJ	
C 4	Rapeseed oil biodiesel: Large areas of grassland are converted into arable land. Rapeseed for bioethanol	LUC^R	=	60 000 ha	1.9
		CS^F	=	70 Mg C	
		CS^{Cl}	=	45 Mg C	
		Δ Agr	=	3 million Mg GE	

Case C	Country in temperate climate zone	Relevant input figures (GE = grain unit)			ILUC in g CO_{2eq}/MJ
	extraction is the key driver.	Δ Agr_{fuel}	=	0.6 million Mg GE	
		$Agr_{fuel, energy}$	=	1.72 E+11 MJ	

Sample Case C describes the conditions in the country in a temperate climate zone. In Variants C1 to C4 it is assumed that there is a functioning land management system and clearly regulated forest protection by law. The results show that even very low, indirect forest conversion rates that are not actually permitted from a legal standpoint, would still produce a relevant figure for iLUC. The sensitivity of the model is thus good. It also shows that the conversion of grassland to cropland which is assumed to be possible in these sample cases slightly increases the iLUC value. The reason is usually only a small difference in carbon between grassland and cropland in temperate zones. An expansion of the biofuels sector to the detriment of grasslands, however, would also produce extremely negative values.

5.3.4 Conclusion of the sample cases

Overall, it was shown that high iLUC values occur in the countries with the highest rain forest deforestation rates that exist today. For those countries that work to protect forests and other carbon-rich natural areas, low iLUC values occur.

The controlling effect of the model to combat iLUC thus exists.

In addition, the calculated sample cases show that the model is sensitive enough to capture even minor iLUC effects in a given timeframe that can occur, for example, when grassland is converted to cropland in central Europe.

Finally, the results above are interesting because the regionally caused iLUC effect that may have originated solely from domestic trade is also high in the model for the countries with high deforestation rates. The possibility of incorporating possible cross-border iLUC effects by means of an individual case review has not yet been included in these results. In cases where this cross-border effect was relevant in the country being analysed, the iLUC values would further increase.

The calculations show that determining the iLUC effects on the basis of regional data is most likely sufficient.

5.4 Criticism for the proposed calculation model

The calculation model described here supplies reproducible results, is transparent in the calculation process and also affects behaviour to the extent that "good governance" also produces positive results with respect to the problem of land use. On the other hand, the fact that, the simplifications, for example, in calculation step 3 are not adequately transparent in the model, cannot be overlooked.

In legal practice, models are allowed to have a margin of error. Models are also allowed to be flawed at the boundary of their "domain of application". What is important is that they prove that they produce generally accurate, plausible and "fair" results in the case of controlling effects as well as scientifically sound results.

Overall, there are a **number of details** of the model that can be criticised:

- Carbon contained in vegetation and soil

The amount of carbon in the vegetation and soil can only be estimated (see Annex A). The soil types, etc. vary in the regions analysed. Consequently, an estimate in three stages is also recommended in the model depending on the level of accuracy that appears necessary. The overall situation is still unsatisfactory. However, this criticism applies equally and, in some case, even more to all other models under discussion. All models deal with this problem in a similar way. Often, very general factors are even used.

The model can, of course, be improved by capturing the carbon stocks in the region in a more differentiated fashion. This option shows the advantages that a regional approach would offer.

- iLUC effects between countries

To capture iLUC effects between countries – which are not as significant for large biofuel exporting countries – an individual analysis that uses a supplemental term is proposed. Control questions are first used in the model to determine whether these types of effects were even significant in the review period. If the answer is yes, the iLUC result determined in the model is increased by a defined factor. This factor is derived from an auxiliary calculation that incorporates the relevant import and export figures. This individual analysis works with uncertain correlations and figures. As a result, this calculation falls into a relatively speculative range as do the agricultural models criticised above. In addition, the control questions and auxiliary calculations recommended here do not capture effects that occur over a longer time period, i.e. effects where cause and effect are separated by many years. This will certainly be criticised. However, it is important to keep in mind how difficult and ultimately how speculative modelling that captures these effects would be. The question of whether or not these effects have great relevance or not needs to be asked.

- Flexibility for increases in yield

Generally, when market prices rise due to an increase in demand for agricultural products like biofuels, the actors are expected to invest in increasing yield (intensification) rather than in acquiring land (see above). This is also anticipated because the intensity of production in the most important biofuel export countries is low, meaning that there is a lot of potential for increasing yield there. These types of effects are not captured directly but indirectly in the model because the real country data is used for the respective calculation. This country data on LUC would be higher in the region in the review period if the calculated increase in agricultural production was not also achieved in part by improving yield, according to the assumption of the model. A similar assumption applies to expanding to previously unused arable land. These effects are also captured indirectly.

- Correction factors

When co-products that go to other agricultural sectors are captured using correction factors, the calculation is a simplified representation. One aspect subject to criticism is that the correction factors are determined by way of the allocation method. However, the efforts of each individual actor to improve efficiency could be pinpointed exactly for every farm using the correction factors[15]. This would have a lot of advantages in terms of the controlling effect. The model could be expanded and, when determining the overall greenhouse gas emissions of biofuels, a reduced "iLUC factor" would possible on a case by case basis, for example, if the farmer were to reuse particularly high value co-products, for instance, as part of the biofuel conversion.

- Cross-border production chain

Individual biofuel raw materials such as soybeans are not usually converted either in full or in part in the producer country. To still be able to use the model for this situation, it is necessary to estimate the quantity of biofuel produced abroad from the agricultural raw materials. Even though figures are available for these estimates, they can, however, be extremely inaccurate.

It would certainly be possible to minimise the criticism above by further developing the model. The quality of the input data could also be improved if a regional model were integrated into a binding legal regulation.

[15] For example, if allocation were carried out at individual farm level.

5.5 Conclusion for "Regional model"

Overall, despite the criticism and restrictions described, the model presented here would already be generally suitable for capturing the regional iLUC effects and calculating a "regional" iLUC factor.

No model calculations were carried out in this chapter for other allocation options for iLUC emissions (see Chapter **5.2.5**). But there are no discernible reasons why the regional results described above cannot be successfully allocated at individual farm level.

6. Various options for combating indirect land use change (iLUC)

In a study [50] commissioned by the WWF, Prognos and the Institute for Applied Ecology (Öko-Institut) emphasise that bioenergy will play a prominent role in climate protection until 2050. This study considers a **reduction in greenhouse gases of approx. 95% from 1990 emissions level necessary in Germany** (approx. 18 Mg CO_{2eq}/E*a). This means that less than 1 ton of greenhouse gases may be emitted per person in 2050 (currently still around 10 Mg CO_{2eq}/[E*a]). According to the authors, Germany can only make its contribution to climate protection by setting an ambitious goal which will allow the international "2-degree target" to be reached.

With respect to the use of biofuels, Prognos/Institute for Applied Ecology (Öko-Institut) found that [50]: "The enormous reductions in emissions call for a strategic re-evaluation of the use of scarce resources for a series of important climate protection options. The use of biomass must not only be examined in view of the quantities available in Europe and the demand for the most efficient use possible, but also with a view to the areas where no alternative to biomass exists in the long-term." Based on this, the authors are of the opinion that using biomass in the mobility sector (biofuels) is a top priority, as shown in Table 13.

Table 13: Assessment of biomass demand in Germany for various scenarios, according to [50]

		Reference scenario			
PJ	2005	2020	2030	2040	2050
Energy consumption					
Biomass	178	184	188	189	188
Biofuels	77	193	268	321	340
Biogas	0	7	16	11	5
Electricity production biomass	136	486	468	432	415
Primary energy	**414**	**908**	**1,042**	**1,092**	**1,089**
		Innovation scenario			
End-use energy consumption					
Biomass	178	189	171	122	66
Biofuels	77	318	708	867	987
Biogas	0	7	16	11	5
Electricity production biomass	136	486	444	394	379
Primary energy	**414**	**1,097**	**1,608**	**1,675**	**1,720**
		Germany model			
End-use energy consumption					
Biomass	178	189	171	122	66
Biofuels	77	318	850	1,136	1,283
Any additional biofuel savings		-107	-246	-326	-391
Biogas	0	7	232	389	443
Electricity production biomass	136	486	444	394	379
Primary energy (with additional biofuel saving)	**414**	**958**	**1,761**	**2,099**	**2,161**
Primary energy (without additional biofuel saving)	**414**	**1,097**	**2,099**	**2,529**	**2,664**
National biomass potential 2050 (rough estimate)					**1,200**

Source: Prognos and Öko-Institut 2009

To tackle the challenges of climate protection policy outlined above, the author of this study feels it is necessary to find effective[16] instruments that prevent further expansion of the cultivation of energy crops (or biofuel production) to the detriment of nature conservation and carbon-rich land.

Which instruments or political options exist to promote the necessary future developments in the biofuel sector without creating negative side effects such as iLUC? This analysis is based on the opportunities for action compiled by Paul Hodson for the EU commission [51].

The author of this study feels that it is important to differentiate between instruments that actually combat or solve the iLUC problem and those that only lead to partial or interim solutions.

6.1 Solutions that get to the root of the problem

There are various feasible solutions that would get to the root of the problem. Three solutions currently under discussion in Europe are described in the following section.

6.1.1 Equal treatment of all agricultural sectors through across-the-board dLUC regulation

First, it is possible according to Hodson [51] to transfer the requirements that apply to biofuels to other agricultural sectors based on the RE Directive ("extend to other commodities .. the restrictions on land use change ...)". If this were successful, not only would a great deal be achieved in terms of environmental protection, it would also create fair competitive conditions for all agricultural sectors in relation to one another. Today, the situation is unsatisfactory because the strict requirements for direct land use change are only imposed on the biofuel sector. If regulations that governed iLUC in these sectors were created for other sectors, iLUC would then be captured as dLUC in these sectors. It would not be necessary to create a special regulation for iLUC in the biofuel sector.

In addition, the global demand for additional land for food and animal feed will be higher than the land the biofuel sector will need in the near future. The additional land that will be required by the food and animal feed sector is projected to be in the range of 190 to 310 million hectares for the year 2020 [52]. Consequently, the sector that also creates the relevant pressure on the land should at least be regulated the same way as the biofuel sector according to other considerations by Hodson.

This idea is coherent and should be intensively supported especially from the perspective of environmental and climate protection. According to this logic, there is actually only one argument for continuing to focus solely on iLUC for the biofuel sector: until the goal of a dLUC regulation has been reached for all agricultural sectors, there must be an interim regulation because it will certainly not be possible to create regulations for land use changes quickly for the other sectors[17]. This would mean that all subsequent political activities would be "**interim solutions**" until a satisfactory dLUC regulation has been implemented. This regulation, similar to the segment for biofuels, could start in Europe and initially be defined unilaterally for the domestic market and key imports/import countries. This would also ensure that, seen chronologically, successes were achieved quickly.

The explanations above make it apparent that the international discussion about iLUC is skewed. Priority is given to incorporating the iLUC effect into the total biofuel greenhouse gas emissions. Justifiably, individual scientists object to this, claiming that this effect by

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16 How effective an instrument is assessed primarily on the basis of its controlling effect.
17 Although the watchful observer has certainly already noticed that regulations are already going in exactly this direction. For example, the efforts for the "carbon footprint".

definition occurs in a sector other than the biofuel sector. The responsibility for this land use change actually lies with the actor who converts land for use in a different sector if one follows the "dogma" of the originator principle that otherwise applies in environmental law. According to this principle, the originator of iLUC is the respective agricultural sector or the actors in this sector who initiate the change in land use. According to the iLUC philosophy which places the originator in the biofuel sector, these actors who are actually "guilty" are held responsible.

One can now argue that the actual originator is the biofuel sector which *indirectly* forces other sectors to clear rain forest, etc. as a result of government imposed climate protection targets and state subsidies. In other similar situations in environmental law, it would not be acceptable to deviate from the principle of the originator. In environmental protection, it is common practice for government regulations to strengthen or weaken individual sectors or actors at the expense of others to reach political goals. In these cases, it is not accepted that the aggrieved sector, for example, is indemnified as compensation for the disadvantages he suffers as a result of scarce environmental goods.

The international discussion at instrument level is not only skewed because the originator principle is violated. Integrating the iLUC effect into the biofuel sector has also been made the focus of political demands and overlooks the fact that a "dLUC regulation for everyone" is actually the right solution (getting to the root of the problem). What actually needs to take place is an intensive national and international discussion about those instruments that would make it possible to quickly apply a dLUC regulation to the animal feed and meets industry similar to for biofuels, i.e. the biofuel standard is introduced. **These contributions to the discussion are difficult to find at present.**

6.1.2 Land use planning

Another way of solving the problem at its root would be to introduce a mandatory land use planning strategy at least into the key agricultural export countries. If this type of regulation were introduced, the land register could initially be set up by type of use (and, if applicable by carbon stocks). These areas could be monitored for land use changes. In addition, this regulation would have to be supplemented by binding legal provisions for land use changes, for example, a ban on clearing forests unless reforestation were to occur in a different location (forest protection law). Similar regulations would have to be created for the grassland sector and for other land deserving of protection. Functioning government monitoring and international reporting would create the necessary confidence in these types of regulations.

Land use planning would allow, among other things, particularly valuable land use (e.g. forest) to increase (net). This could be combined with international efforts to reduce emissions through reforestation (UN REDD Initiative [53]).

6.1.3 Conclusion of an international convention for land protection

Finally, a binding regulation to protect carbon-rich land could be adopted in an international convention. This regulation could be drafted under the scope of the UN REDD discussions or integrated into ongoing climate protection negotiations for the post-Kyoto period.

This idea is not new. It is being worked on in various places. Of course, this type of convention would only be able to work if it were equipped with appropriate compliance mechanisms and sanctions. The sceptical arguments against a solution to the problem in this form thus add up in the overall thoughts of whether an internationally binding climate protection policy could be successful.

6.2 Interim solutions

Several different interim solutions are under discussion.

6.2.1 No action

One possible interim solution would be not to implement any special regulations for integrating iLUC into the RE Directive. This option would certainly be favourable if the EU Commission announced that it wanted to work on a solution that gets to the root of the problem at the same time. Assuming that the timeframe for this project is reasonable, this option can certainly be considered worthy of discussion as introducing an interim iLUC regulation is associated with a lot of time and money. If, for example, it were announced that dLUC would be documented and regulated for other sectors, a lot more would be achieved for rain forest protection and protecting other valuable natural regions than with an interim solution in the relatively small biofuel sector. As a result, it is certainly easy to agree that the focus of the administrative and political forces should be on finding an across-the-board solution to the problem.

If the political will or the opportunity for this process does not exist, other interim solutions would have to be considered. The following section describes possible solutions.

6.2.2 Interim solution: "Stricter RE requirements"

One possibility would be to make the requirements for greenhouse gas savings for biofuels stricter [51]. In this way, the minimum requirements for greenhouse gas emissions savings could be raised by several percentages in the RE Directive. The result would be that it would no longer be possible to sell less efficiently produced biofuels. Because, however, one of the supposed primary originators for unfavourable land use change, namely palm oil plantations, demonstrates a relatively good greenhouse gas balance, it is possible that something would be improved overall in terms of climate protection but not much would be achieved in terms of the controlling effect to prevent iLUC.

6.2.3 Interim solution "Additional bonuses"

Another interim solution would be to strengthen the bonus model in the RE Directive [51]. This way, in addition to the bonus for growing biofuels on fallow land, bonuses could also be granted for extracting biofuels from waste biomass, for intensifying cultivation or increasing production efficiency. The controlling effect overall, however, would be only limited with this interim solution.

6.2.4 Interim solution: "Black list"

A "black list" could be created by regions or countries where iLUC or land use changes above a minimum threshold have been identified in valuable natural regions. Biofuels that originated from these "black-listed countries" would not be compatible with the RE Directives in Europe. This approach would certainly be practical as an interim solution and could be implemented with a reasonable amount of time and effort and would also surely have the required far-reaching effect but would probably be illegal or incompatible with international treaties (WTO).

6.2.5 Interim solution: "Bilateral agreements"

One operative variant for combating iLUC would be if Europe were to focus the ongoing discussions with important biofuel producers like Brazil or Indonesia on concluding bilateral agreements. These agreements could include concessions for the countries to undertake the measures necessary to combat land use changes domestically.

The advantage of bilateral agreements is that they would be successful much more quickly than finding an across-the-board solution to the problem. It would also be possible to only conclude agreements initially with individual "well-meaning" countries to increase the pressure on the other countries. Another advantage of this option is that that the discussion would not just revolve around biofuels. It would be possible to come up with an across-the-board land use regulation in these countries through the discussion about biofuels. One essential element of this option is the pressure that Europe can apply to arrive at bilateral agreements. Restricted access to the European market is probably the most effective way to apply pressure. However, the structure of this option would have to be compatible with the WTO. Another key component of this option is whether it is possible to develop a legally valid regional model that plausibly represents and quantifies the iLUC conditions in the respective country (see below).

6.2.6 Interim solution: "Introduction of a regional iLUC factor"

Another approach would be to impose additional requirements on countries where land use changes, for example rain forest clearance, were known [51]. To this end, a regional iLUC factor defined for biofuels from the respective region by the Commission could be added to the RE regulation. Essentially, proof that the biofuel sector is not partially responsible for the land use change could be required for this region. If the country is not able to furnish this proof, the Commission could calculate an iLUC factor based on the land use data of the respective country using a standard calculation model in Europe and add all biofuels from this region as a risk adder. If the risk adder caused the RE limit values to be exceeded, the biofuel could no longer be sold in Europe. One argument in favour of this proposal is that it gives the Commission considerable leverage up front to achieve concessions in combating iLUC vis-à-vis the respective country.

As described in Chapter **5.2.5**, there are different ways to allocate the regional calculation of iLUC emissions. Emissions, for example, can be allocated all the way down to individual farm level. The advantages and disadvantages of the different options have been analysed above. For the instrument analysis to be conducted in this chapter, it is important that these options open up negotiating room for the EU Commission to be able to respond to objections.

6.2.7 Interim solution: "Introduction of a global iLUC factor"

A global iLUC factor could also be incorporated into European biofuel law. A global risk adder that expresses the iLUC effect in CO_2 equivalents would be added to the greenhouse gas savings in the RE Directive. There is a wide range of different ideas and proposals for this risk adder (see above). The main problem of this proposal is that the iLUC effect cannot be calculated with simple methods at global level (see above). The global iLUC factor would have to be calculated by means of one of the models described above. The agricultural economic or a deterministic model could be considered for this purpose.

6.2.8 Interim solution: "Introduction of an iLUC model"

Finally, one of the agricultural models mentioned above (following additional improvement if necessary) for calculating iLUC could be incorporated directly into the greenhouse gas total according to the RE Directive.

6.3 Analysis of a comparison of different options for action.

In the following section, an analysis of how the advantages and disadvantages of the instruments and options for action compare is provided. As explained, introducing and monitoring binding dLUC regulations for all agricultural sectors would have the best effect on environmental protection and nature conservation by far. The same applies to a regulation that works via regional land use policy and introduces binding protection and compensation mechanisms to combat dLUC/iLUC. The adoption of an international convention to protect valuable carbon stocks is, strictly speaking, an operative variant to solve the root of the problem described. The widespread criticism that achieving this goal would not happen immediately or could only happen over the long term does not change the fact that this is the right goal and an important one. But striving to solve the problem at its root should not be misunderstood as an alternative to identifying interim solutions. On the contrary, it will probably become necessary to define interim solutions at the same time because it will take a long time to reach these goals[18].

But all of the proposed interim solutions should also be assessed in terms of to what extent they bring us closer to achieving the actual goal of identifying an across-the-board solution to the problem.

It is the opinion of this study's author that proposals which represent iLUC to political decision-makers as a problem *particular* to biofuels are less beneficial. Decision-makers then expect to be able to solve the iLUC problem by reaching a political decision about the biofuel sector in the RE Directive. Also less conducive would be proposals that threatened to fail due to their scientifically disputed or extremely flimsy basis (politically or legally) and thus pose the political risk of discrediting the long-term goal described here.

An appropriate interim solution should capture the CO_2 effect of iLUC as accurately as possible. It therefore has to be ensured that the calculation results **can be reproduced**. Another criterion for the suitability of an interim solution is its **transparency, not only** in the calculation process itself, but also in the resulting political effects.

One decisive criterion in determining the suitability of the model is its subsequent environmental policy effect and/or its **controlling effect**. iLUC has to be combated effectively through interim solutions. In addition, if "good governance" takes place in a region in terms of iLUC, the results need to reflect this (and vice-versa).

Seen in this light, the interim solutions "Stricter requirements" and "Bonuses" are certainly reproducible and transparent but relatively limited in their controlling effect.

The interim solution "Black list" satisfies all three criteria. Transparency, of course, only exists if there are clear rules for adding countries to the list. The proposal has, perhaps, certain drawbacks with respect to its controlling effect because it does not offer much room to negotiate with the countries. It only deals with the question of whether a country should be placed on the list or not. The main argument against this proposal is whether or not it is

18 Unless there is sufficient political will at EU level to focus all available forces on solving the fundamental iLUC problem.

legal. A "diplomatic" aspect also of course needs to be thrown into the mix as far as the way Europe deals with developing and emerging countries.

The "bilateral agreements" feature a number of advantages. In particular, the different conditions in each country can be addressed in a differentiated fashion and clear arrangements reached for monitoring the agreements. The "Remote Sensing" instrument [54] also gives Europe an independent instrument to monitor compliance with the agreements. One drawback is that only one country is initially captured and there will be countries that will withdraw or want to withdraw from a bilateral agreement for different reasons.

The disadvantage of the global iLUC factor is that it has to be developed using mathematical agricultural models that produce very different results. As explained, this is essentially associated with the desire or need to represent the global iLUC effect. The models are thus not adequately reproducible or transparent.

The same objections exist to only incorporating the mathematical model for calculating an individual iLUC value into the RE Directive and not a global iLUC factor. The same objections also exist to using agro-economic models for calculating iLUC in regulations and not a global iLUC factor. In this case, the described frequency distribution of the results, for example, would become a problem of enforcing the RE Directive. Alternatively, it would be possible to integrate one of the different models for iLUC calculation into a legislative regulation. This would imply that the most well-suited model should be identified and that the model should be selected and its validity discussed within the framework of the political decision-making process for modification of the RE Directive.

Global deterministic models, with their high level of transparency, are much better than mathematical agricultural models. The most important disadvantage is the relatively simple model constellation for representing highly complex global correlations.

Another argument against a global iLUC factor or a global mathematical agricultural model is that the controlling effect for combating iLUC cannot be differentiated. The global factor or the global model applies to all biofuels (or to individual types of biofuels) worldwide. It doesn’t matter whether the fuel originates from a region where iLUC is being successfully combated through committed political decisions or not. Generally biofuels that demonstrate high land yield based on the given climate situation (and thus a positive greenhouse gas total) are also generally put at an advantage using a standardised global factor. These are unfortunately often biofuels in the regions where there is a great risk of iLUC.

A **regional iLUC factor**, on the other hand, has a differentiated controlling effect. As long as the land use policy results in minimal land use changes and protects carbon-rich land in a region, this could be captured and would also bring the regional actors advantages in greenhouse gas totals of biofuels. If a land policy were in place that, for example, resulted in an increase in forests, positive iLUC values could be achieved regionally.

Different possibilities for combinations of options should be considered in the instrumental analysis. One combination that appears interesting is calculating regional iLUC factors together with the "bilateral agreement" solution. This combination of solutions could initially support negotiations because determining the regional conditions would supply the reasons for concluding an agreement. If the respective country is noticeably unwilling to agree to a mutual solution, a regional iLUC factor could be introduced to the greenhouse gas totals of biofuels from this region. A corresponding option for defining a regional iLUC factor could be incorporated into EU law in the RE Directive. This would also increase pressure to conclude bilateral agreements. It would be desirable for the bilateral regulations to not only address the iLUC effects from the biofuel sector but also the indirect land use effects of the other agricultural sectors.

7. Conclusion

There is certainly consensus that "something needs to be done" to combat land use change. There is currently **no consensus**, however, about **what can be done**.

The most important negative effect of an iLUC effect is increased greenhouse gas emissions due to the loss of forests (deforestation). Deforestation is caused by many factors. These include an increasing demand for food, more meat consumption but also more demand for energy crops and, as a sub-quantity, the demand for biofuels, plus many other social and institutional causes.

The political difficulty is that a hypothesis or a phenomenon that only has indirect effects via complex correlations is to be combated and is also very difficult to capture and quantify scientifically (iLUC effect). This applies in particular to globally oriented models. In addition, as explained above, the biofuel sector currently only causes a relatively small part of the entire iLUC effect. Therefore, from the author's perspective, global iLUC factors are not suitable for legal solutions.

In contrast to globally capturing and quantifying iLUC, a regional approach based on the existing country statistics makes it possible to calculate the iLUC effects brought about by biofuels in this region relatively reliably. The results can be reproduced and are robust, the calculation process is transparent and the controlling effect allows, for example, *good* *governance* to be captured and rewarded (and vice-versa). In addition, there are various options for structuring a regional model with different controlling effects which opens up decision-making flexibility in the political discussion. The weaknesses of the model presented here are being discussed and can be minimised by working further on the model. Crucial, however, is the political analysis of the **advantages of a regional approach in providing a solution to the problem of iLUC**.

Solutions that get to the root of the problem, independently of the quantitative significance of the iLUC effect, can be achieved by expanding the biofuel regulations from the RE Directive to other agricultural sectors or through binding introduction of land use planning and protection strategies in the key agricultural countries.

Bilateral agreements between the EU and important agricultural countries like Brazil, Indonesia/Malaysia or Argentina could represent a first step in the right direction and could prepare the solution to the problem identified above. It would be desirable in terms of environmental protection to include the other agricultural sectors in addition to the biofuel sector due to the high percentage they contribute to the iLUC effect.
It would also be justified, however, to only initially address the biofuel sector as an interim solution and then to include the other sectors.

Adding an option to the RE Directive is recommended: the EU Commission should be given the ability to calculate and define a regional iLUC factor for a country given defined political conditions. These conditions include, in particular, a documented and long-term refusal of a country to agree with the EU to a bilateral agreement as the solution to the problem. Another helpful condition for increasing the negotiating pressure would certainly be if the basic structure of the model were also anchored in laws for determining the regional iLUC factor. **Overall a combination of activities made up of a medium to long-term international solution and short-term interim solutions through various "bilateral agreements" supported by a regional iLUC model is recommended.**

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Market development for CPO in Indonesia (in t)

Year	Production	Export	Import	Consumption
2005	11,861,615	10,375,792	10,810	1,496,633
2006	17,350,848	10,471,915	1,645	6,880,578
2007	17,664,725	11,875,418	1,067	5,790,374
2008	19,200,000	18,141,004	11,721	1,070,717
2009*)	19,440,000	14,981,467	10,591	4,469,415

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9. Annex: Data basis for determining CS

Table 14: Carbon stock (in vegetation and soil) for different land uses, in Mg C/ha (various sources, in particular [29])

Land use	"CS" carbon stock
"Rain forest", **default**	300 Mg C/ha
"Rain forest", Asia, soil = 0	205 Mg C/ha
"Rain forest", Asia, peatland	970 Mg C/ha
"Rain forest", Amazon	265 Mg C/ha
"Forest", **default**	150 Mg C/ha
"Forest" North America	140 Mg C/ha
"Forest" Europe	130 Mg C/ha
Plantation	110 – 130 Mg C/ha
Wetland	100 Mg C/ha
Grassland, **default**	100 Mg C/ha
"Bush", Africa	90 Mg C/ha
"Woody cerrado", South America	75 Mg C/ha
"Grassy cerrado", South America	65 Mg C/ha
"Savanna" wet	130 Mg C/ha
"Grassland" tropical	75 Mg C/ha
"Grassland" temperate	70 Mg C/ha
"Pasture" temperate, minimal	40 Mg C/ha
"Cropland" annual harvest, default	55 Mg C/ha
"Cropland" annual harvest, soil = 40	45 Mg C/ha
"Cropland" annual harvest, minimal	30 Mg C/ha

If there is a special case – the default values in the table above are not suitable or don't apply or the differentiated information is not sufficiently accurate in the following tables – or the land use change is larger in scale, requiring more calculation of CS, the IPCC calculation methods can be used [29]. This method is globally recognised and can be carried out with reasonable effort. We will not provide an explanation of the IPCC method for calculating "**CS**" here.

When calculating the emissions arising from land use changes, it is assumed that, after conversion, the carbon stock of the original use was completely changed to the level of current use after a 20-year period.

Table 15: CS of the vegetation in Mg C / ha (29)

Land use	CS vegetation in Mg C/ha
Tropical rain forest	200
Tropical humid summer green forest	127
Tropical dry forest	103
Tropical bushland	46
Tropical mountain forest	90
Sub-tropical wet forest	132
Sub-tropical dry forest	107
Sub-tropical steppe	43
Sub-tropical mountain forest	26
Temperate oceanic forest	202
Temperate continental forest	52
Temperate mountain forest	64
Boreal, conifers	33
Boreal, tundra	13
Boreal, mountain forest	39
Grassland, boreal, dry & wet	2
Grassland, cold, temperate, dry	3
Grassland, cold, temperate, wet	5
Grassland, warm, temperate, dry	2
Grassland, warm, temperate, wet	5
Grassland, tropical, dry	3
Grassland, wet & dry	6
Cropland, annual crop	0

The use of default values or estimates is only an attempt to provide an approximate picture of the actual situation. This shortcoming cannot, however, be used as a reason to reject the model proposed here because mean values and across-the-board assumptions for CS as used in all of the currently proposed models and essentially would also need to be formulated for the current calculations of emissions arising from land use changes in accordance with the RE Directive.

Table 16: CS in the mineral soil under the vegetation, in Mg C/ha [29]

Climate region	Highly active loamy soil	Loamy soil with low activity	Sandy soil	Podzol	Volcanic soil	Wetland
Boreal	68		10	117	20	146
Cold temperate, dry	50	33	34		20	87
Cold temperate, wet	95	85	71	115	139	87
Warm, temperate, dry	38	24	19		70	88
Warm, temperate, wet	88	63	34		80	88
Tropical, dry	38	35	31		50	86
Tropical, humid	65	47	39		70	86
Tropical, wet	44	60	66		130	86
Tropical, mountain	88	63	34		80	86

Table 17: Emission factors for drained organic soils in C per hectare and year [29]

Climate zone	Emission factor in Mg C /ha and a
Forest, tropics	1.36
Forest, temperate	0.68
Forest, boreal	0.16
Grassland, boreal, cold, temperate	0.25
Grassland, warm, temperate	2.5
Grassland, tropical, sub-tropical	5

Table 18: Calculation of the land use change values for a selection of biofuels of the "default table" of the Biomass Sustainability Ordinance[19]

		Wheat Europe	Corn North America	Sugarcane tropical Latin America	Sugar beet Europe	Rape seed oil Europe	Soybean oil tropical Latin America	Palm oil Southeast Asia
Initial use	**t_c/ha**	**Grassland**	**Grassland**	**Savanna**	**Grassland**	**Grassland**	**Savanna**	**Rain forest**
Est. carbon stock	t_c/ha	70	70	134	70	70	134	265
Biomass above and below ground	t_c/ha	6,3	6,3	87	6,3	6,3	87	205
Soil storage	t_c/ha	63	63	47	63	63	47	60
Use		**Arable land**	**Arable land**	**Arable land**	**Arable land**	**Arable land**	**Arable land**	**Plantation**
Est. carbon stock	t_c/ha	55	55	55	55	55	55	110
Biomass above and below ground	t_c/ha	5	5	7,5	5	5	5	50
Soil storage	t_c/ha	50	50	47,5	50	50	48	60
Change a)	**t_c/ha**	**-15**	**-15**	**-79**	**-15**	**-15**	**-81**	**-155**
	A	20	20	20	20	20	20	20
Annualised	t_c/(ha*a)	0,75	0,75	3,95	0,75	0,75	4,05	7,75
Emission result	t CO_2/(ha*a)	**2,75**	**2,75**	**14,5**	**2,75**	**2,75**	**14,8**	**28,7**
Special land requirement								
without allocation	ha/GJ	0,0174	0,0131	0,0121	0,0089	0,0200	0,0607	0,0079
with allocation	ha/GJ	0,0095	0,0072	0,0107	0,0057	0,0107	0,0168	0,0038
Emissions in relation to biofuel								
without allocation	kg CO_2eq./GJ	**47,8**	**36,1**	**175,5**	**24,5**	**54,9**	**901,1**	**223,9**
with allocation b)	kg CO_2eq./GJ	26,2	19,8	154,7	15,6	32,8	282,4	106,6

a) Negative values correspond to a loss of carbon stocks
b) Inclusion of the allocations based on the lower energy content value across the production chain through to the final product (Ethanol, FSME)

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