Making two parallel land-use sector debates meet: Carbon leakage and indirect land-use change

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Abstract

Several land-based policy options are discussed within the current quest for feasible climate change mitigation options, among them the creation and conservation of forest carbon sinks through mechanisms such as Reducing Emissions from Deforestation and Forest Degradation also called REDD+ and the substitution of fossil fuels through biofuels, as legislated in the EU Renewable Energy Directive. While those two policy processes face several methodological challenges, there is one issue that both processes encounter: the displacement of land use and the related emissions, which is referred to as carbon leakage in the context of emissions accounting, and indirect land-use change also called ILUC within the bioenergy realm. The debates surrounding carbon leakage and indirect land-use change issues run in parallel but are rather isolated from each other, without much interaction. This paper analyzes the similarities and differences as well as common challenges within these parallel debates by the use of peer-reviewed articles and reports, with a focus on approaches to address and methods to quantify emissions at national and international scale. The aim is to assess the potential to use synergies and learn from the two debates to optimize climate benefits. The results show that the similarities are many, while the differences between carbon leakage and ILUC are found in the actual commodity at stake and to some degree in the policy forum in which the debate is taken. The geographical scale, actors and parties involved also play a role. Both processes operate under the same theoretical assumption and face the same problem of lacking methods to quantify the emissions caused by international displacement. The approach to international displacement is one of the main differences; while US and EU biofuel policymakers acknowledge uncertainties in ILUC accounting but strive to reduce them, the United Nations Framework Convention on Climate Change excludes accounting for international carbon leakage. Potential explanations behind these differences lie in the liability issue and the underlying accounting principles of producer responsibility for carbon leakage and consumer responsibility for ILUC. This is also reflected on the level of lobby activities, where ILUC has reached greater public and policy interest than carbon leakage. Finally, a possible way forward for international leakage accounting in future climate treaties could be the adoption of accounting methods taking a consumer perspective, to be used alongside the existing set-up, which could improve climate integrity of land-based policies.

Keywords: carbon-accounting system, climate policy, greenhouse-gas emissions, forest conservation, land-use competition

1. Introduction

The effectiveness of climate change mitigation action in the land-use sector, for example through the Clean Development Mechanism (CDM) or Reducing Emissions from Deforestation and Forest Degradation (REDD+), is constantly discussed in climate policy forums such as the United Nations

Framework Convention on Climate Change (UNFCCC). The effectiveness of reducing greenhouse-gas (GHG) emissions has also been discussed vividly in the context of bioenergy and biofuel policies in the United States (US) and European Union (EU). Alongside these discussions at policy level, aspects of effectiveness debated within academia have included actual climate effectiveness (e.g., Henders and Ostwald 2012), sustainable development (e.g., Sonwa et al. 2012) or cost efficiency (e.g., Hedenus and Azar 2009), as well as the concept of 3E+ in REDD+; effective and efficient emission reduction with equitable impacts of co-benefits (see Angelsen et al. 2009; Angelsen et al. 2012).

There are many methodological challenges to effectiveness when implementing a climate policy focusing on land use. If these hurdles are not properly addressed, the climate effectiveness of the policy, in terms of avoiding GHG emissions or increasing sinks, might be undermined or even reversed. Examples of such methodological challenges from the REDD+ debate are the creation of baselines or reference levels against which an intervention should measure its performance, or ensuring additionality, which implies demonstrating that the effect of the intervention would not have happened in its absence. Such hurdles within the biofuel debate include ensuring that the substituting biomass has a lower emission factor than the fossil fuel it is supposed to replace. Another such issue threatening the effectiveness of climate policy is that of land-use displacement as a response to interventions that aim to reduce GHG emissions, which is in focus in this paper.

Here we focus on two parallel debates within the field of climate change mitigation and land use: the issue of carbon leakage within forest conservation efforts such as REDD+ and the issue of indirect land-use change (ILUC) within the bioenergy production sector. We only relate to the concept of carbon, carbon stocks and carbon emissions while disregarding other impacts such as biodiversity, water and soil. The concepts of carbon leakage and ILUC both work under the conceptual understanding of land-use displacement and face the same challenges in quantifying indirect, non-measurable effects. We will primarily base our analysis on *how* carbon leakage and ILUC can be assessed, in other words which approaches exist to address and what methods are available to quantify these unintended impacts. This issue is of policy relevance, or as presented by Nassar et al. (2011, p. 225) “Policy makers find themselves in a chicken and egg situation: they know that [indirect] LUC [land-use change] emissions have the potential to undermine [policies aiming at] GHG savings, but they are hesitant in setting a value for LUC emissions because there are still several uncertainties associated with the methodologies available”.

Through text analysis information is sought from peer-reviewed literature and related reports, starting from the work on assessing carbon leakage methods by Henders and Ostwald (2012), and the ILUC dilemma described by Gawel and Ludwig (2011). The aim is then to compare approaches and quantification methods for carbon leakage and ILUC, identify overlaps in methods, application and applicability, and analyze the similarities and differences as well as common challenges within these parallel debates to see if there is room for synergies in the quest to optimize climate benefits.

2. The concept of carbon leakage

Carbon leakage can be defined as displacement of carbon or GHG emissions from one place to another due to emission reduction interventions. Displacement and emission can happen domestically or internationally, where the latter is of interest here due to the focus on the global scale implications of REDD+ and biofuels. Displacement is caused by a direct or indirect shift of activities that create those emissions from within an emissions accounting system to outside of that system (Henders and Ostwald 2012). The IPCC defines carbon leakage as the unanticipated increase or decrease (the latter is called positive or benign leakage and is generally unaccounted for) in GHG benefits outside of the project's accounting boundary as a result of the project activities (IPCC 2000). This definition is mainly applicable for local scale emission reduction project activities; however leakage can also occur on international scales, when emission-related policies are adopted in one place and emissions shift to a place where this policy is not effective (Murray 2008). Carbon leakage is therefore most likely to happen when the scale of the intervention is smaller than the scale of the overall problem (Wunder 2008), which would mean that in a global climate agreement there would be no leakage because displaced emissions would be accounted for wherever they occur.

Carbon leakage has the potential to undermine the effectiveness of climate change mitigation under the UNFCCC and even though the phenomenon can occur in all sectors, there has been strong focus on land use and forest interventions such as afforestation and reforestation (A/R) or REDD+. Carbon leakage was one of the main methodological concerns why avoided deforestation was excluded from the CDM in 2001 (Skutsch et al. 2007; Sohngen et al. 2008). Responding to the discussions about carbon leakage in the land-use sector within the Kyoto Protocol negotiations, the scientific literature has addressed the issue on conceptual and methodological levels.

Conceptionally, the debate within the scientific arena has framed key definitions concerning carbon leakage (e.g., Sathaye and Andrasko 2007). Two basic types of carbon leakage can be distinguished; primary and secondary leakage (Table 1). Primary or direct leakage is caused by displacement of activities or agents from one area to another. This is usually referred to as activity shifting and happens when a forest conservation activity reduces land availability for activities such as shifting cultivation or fuel wood collection that move to another forest area to continue. Secondary leakage happens when forest conservation in one place indirectly creates incentives to deforest elsewhere (Aukland et al. 2003). This can happen when there is a reduction in supply of a commercial product (e.g., timber), which leads to a shift in market equilibrium. Hence this type of leakage is sometimes referred to as the market effect (Schwarze et al. 2002). The difference to primary leakage is that the forest conservation activity causes incentives for others to start deforest, rather than moving the initial deforestation agent. The distinction between the two leakage types can however be less evident in the cases of large land-based commercial interventions (e.g., palm oil companies) that are involved in many geographical areas. In these cases conservation actions affecting the company in one place can cause market effects, but it might be the same agent that causes displacement. Observe in Table 1 that within ILUC no difference is made between primary and secondary effects, and both are referred to as indirect land-use change. The terms described in Table 1 refer to land-use changes in a climate-policy context, they are not or only partly applicable for land-use change processes in general.

Table 1 near here

Carbon leakage can take place on all geographical scales depending on the drivers of deforestation. It can be a local process mainly when smallholders or local communities are affected in subsistence activities such as small-scale agriculture and firewood collection. These small-scale processes are clearly a responsibility within the country where they occur. Carbon leakage can also be an international phenomenon when global players or production of market commodities are affected. At this scale it is harder to account for the displaced emissions if they take place in another country than the intervention itself (Skutsch et al. 2007).

Modeling exercises of carbon leakage from forest conservation yield large ranges, which indicate the potential magnitude of the problem as well as uncertainties in assumptions and quantification (see Henders and Ostwald 2012). When it comes to market effects from forest conservation, improved forest management and afforestation, studies modeling international leakage show that 42-95 % (Gan and McCarl 2007) or 47-52 % (Sun and Sohngen 2009) of the possible emission reductions could be offset by leakage. National scale assessments also based on equilibrium models yield market effects of 5-42 % for Bolivia (Sohngen and Brown 2004) and 18-42 % for the US (Murray et al. 2004). In an assessment of direct leakage, Lasco et al. (2007) found regional-scale leakage from forest conservation, afforestation and agroforestry activities in a watershed in the Philippines to be in the range of 19-41 %.

At present, methods and tools to quantify carbon leakage exist within several carbon market standards, such as the CDM, Verified Carbon Standard (VCS), Climate Action Reserve (CAR) and the Carbon Fix Standard (CFS). While these tools are suitable to quantify carbon leakage effects on the national scale, they do not address quantification of international leakage, as this is beyond the scope of current emission accounting frameworks (Henders and Ostwald 2012). The few available assessments of international leakage effects are exclusively found in the scientific literature.

It seems that carbon leakage at national scale is well addressed within current emissions accounting frameworks; however considering the leakage estimates cited above, the lack of methods for international leakage could substantially affect the effectiveness of REDD+ activities. While we compare methods for both within-country and international displacement effects in this paper, the central discussion emphasizes findings relevant for international leakage and implications for carbon accounting.

3. The concept of ILUC

A definition of ILUC is when land formerly used for cultivation of food, feed, or fiber is now used to cultivate plant material for biofuel production, shifting original land use to an alternative area that might have a higher carbon stock (e.g., forest) (Gawel and Ludwig 2011). ILUC is a quite recent issue strongly connected to indirect emissions from biofuel production.

Up to 2008, several full life-cycle studies had found that corn ethanol, cellulosic ethanol and Brazilian sugarcane ethanol produce lower GHG emissions than gasoline (e.g., Macedo et al. 2004; Wang 2005; Farrel et al. 2006; UK Department of Transport 2008; Sperling and Gordon 2009). However, none of these studies considered the effects of ILUC. Although land-use impacts were acknowledged, estimation was considered too complex and difficult to model, until the paper by Searchinger et al. (2008) was published. This controversial paper found that ILUC effects potentially overruled the GHG saving effect of both corn and cellulosic ethanol in the US and generated emissions of 107 grams CO_2 per megajoule (gCO_2eq/MJ). The same effect was identified by Fargione et al. (2008), who simultaneously published a paper claiming that clearing lands to produce biofuel feedstock created a carbon deficit, stemming both from direct and indirect land-use changes. The carbon debt was defined as the amount of CO_2 released during the first 50 years of this process of land conversion.

After those papers, estimation of carbon emissions from ILUC, together with the food vs. fuel debate, became one of the most contentious issues relating to biofuels, debated in the popular media (e.g., Time Magazine 2008a,b,c; The New York Times 2008; The Wall Street Journal 2008; The Economist 2009) as well as academia and the scientific community (e.g., Kleiner 2008; Searchinger 2008; Kline and Dale 2008). Further research supported those early findings of potentially large ILUC effects. Melillo et al. (2009) projected with the help of a combined economic-biophysical model that ILUC would contribute twice the amount of carbon loss than direct land-use change in the case of a global biofuel program over the 21st century. Lapola et al. (2010) used simulation modeling and estimated 60 % deforestation in Amazon between 2003 and 2020 being attributed to ILUC from biofuel production. Hertel et al. (2010) used the GTAP model to determine ILUC from US corn production for ethanol and projected ILUC emissions of 27 gCO_2eq/MJ, with a range of 15-90 gCO_2eq/MJ. To put these figures into context, the emission factor of gasoline is 74 gCO_2eq/MJ (Wang et al. 2012) (IPCC suggests emission factors in the range of 69-74 gCO_2eq/MJ for motor gasoline and gas/diesel oil (IPCC 2006)). Dumortier et al. (2011) used the same model that Searchinger et al. (2008) applied in their analysis, but included a sensitivity analysis of the main assumptions. They established a range of ILUC emissions from corn ethanol of 14-65 gCO_2eq/MJ. Hellmann and Verburg (2011) simulated different land-use change scenarios within the EU in a spatially explicit analysis of the impacts of EU biofuel policies and found that indirect effects are much larger than the direct effects. This finding was supported by Lange (2011), who concluded that the EU's current focus on minimizing DLUC will intensify the competition between biofuel and food production and hence increase global ILUC effects.

As consequence of those developments, in 2009 the California Air Resources Board (CARB) decided to include modeling of ILUC impacts into the California Low-Carbon Fuel Standard, which entered into force in 2011. Also, the US Environmental Protection Agency (EPA) has since 2010 incorporated ILUC effects in the Renewable Fuel Standard, which requires addressing ILUC based on modeling (US EPA 2010a,b). While US biofuel policies thus rely on modeling approaches towards ILUC effects, the EU Parliament is still undecided how to best address ILUC in its Renewable Energy Directive. In 2008, a report by the UK's Renewable Fuels Agency (RFA 2008) found that the quantification of GHG emissions from ILUC involves subjective assumptions and considerable uncertainty. The European Parliament adopted more stringent sustainability criteria for biofuels in 2008 that cover direct land-use change but not indirect effects (European Parliament 2008). Instead, the European Commission has been requested to develop a methodology to factor in GHG emissions from ILUC, which is now a proposal since October 2012 (European Commission 2012). In response to this, several studies have been produced to analyse the potential impacts of EU biofuel policies (e.g., JRC 2010; Banse et al. 2011; IFPRI 2011; Prins et al. 2011; Di Lucia et al. 2012; Wicke et al. 2012). Most of those studies rely on combined economic and biophysical models, which is the most common approach to determining ILUC effects (see Netherlands Environmental Assessment Agency (PBL) 2010; Nassar et al. 2011; Davis et al. 2011 for reviews on ILUC modeling options). While the two US biofuel policies have chosen their preferred ILUC model (GTAP in California, Fasom/FAPRI in federal RFS), several models are still being explored within the EU for its Renewable Energy Directive and the Fuel Quality Directive (e.g., AGLINK, MIRAGE, CAPRI, LEITAP, GTAP).

Most major modeling applications indicate the importance of ILUC effects in the environmental assessment of biofuels, however the results show large variations due to different underlying assumptions and crops. Figure 1 provides an overview of ILUC emissions findings from different scenarios. Note that the findings do not include life-cycle emissions from the total biofuel production chain and that emissions from gasoline are 74 gCO_2 eq/MJ (Wang et al. 2012). In some scenarios, ILUC effects alone outweigh gasoline life-cycle emissions, while other scenarios estimate lower ILUC effects that however combined with general life-cycle assessment effects still exceed emissions from conventional fuels.

Figure 1 near here

Due to these huge variations several recent studies conclude that a suitable model for evaluating global ILUC effects is at present not available (Netherlands Environmental Assessment Agency (PBL) 2010; Dumortier et al. 2011; Fritsche and Wiegmann 2011; Gawel and Ludwig 2011; Nasser et al. 2011). Van Stappen et al. (2011) state that estimating ILUC requires a detailed understanding of the drivers of LUC along with a trade and economic model with country-by-country and crop-by-crop data. Here, Nassar et al. (2011) conclude that deforestation drivers, although included in several models for ILUC/leakage, are not well enough known to be represented in mathematical equations and economic parameters, which is one of the factors contributing to uncertainties related to model results.

4. Carbon leakage and ILUC: Similarities and differences

4. 1 Underlying assumptions

Both carbon leakage and ILUC work under the same conceptual understanding or assumption of *land-use displacement* causing emissions in order to fulfill a continued or increasing demand (see e.g., Skutsch et al. 2007; Melillo et al. 2009; Meyfroidt et al. 2010; Gawel and Ludwig 2011; Lambin and Meyfroidt 2011; Henders and Ostwald 2012). Although indirect effects can also be positive (e.g., through reduced emissions as result of displacement), carbon leakage and ILUC are usually assumed to have negative effects. This is definitely the case in a short-term perspective; if displacement causes land-use changes that generate carbon emissions. If seen from a long-term forest transition perspective (Mather 1992), displacement causing forest loss will occur as long as farmers seek more productive land. Meyfroidt et al. (2010) argue that if seen over time and across nations, this process could eventually lead to net reforestation since the less productive lands will be abandoned and regenerate forest, hence the process could eventually create a global forest transition.

While strictly speaking, ILUC also represents a leakage effect (Gawel and Ludwig 2011; Lambin and Meyfroidt 2011), there are differences between the concept of carbon leakage and the concept of ILUC as applied here: Carbon leakage describes the effect of indirect land-use changes that cause deforestation, and aims to quantify the related emissions impact. The focus is here on the land-use change process, but leakage assessments seek to identify and account for different drivers behind deforestation by distinguishing direct/primary and indirect/secondary displacement effects (Henders and Ostwald 2012). Accordingly, methods to quantify carbon leakage emissions differ between the two types: primary leakage methods usually measure and map land-use change effects in the field, while secondary leakage is estimated with the help of models or discount values.

ILUC assessments on the other hand start from a different perspective by considering only one type of land-use change driver; the expansion of biofuel plantations, and tracing its impacts on global agricultural commodity markets (Fritsche and Wiegmann 2011). ILUC is understood as a spatial-temporal market-driven effect with a global scope (Panichelli and Gnansounou 2008). Thereby no distinction is made between the type of displacement so that both primary and secondary displacement is considered as indirect land-use change (Table 1), and quantification methods usually target agriculture commodity markets and their land demand.

In that sense, carbon leakage assessments more holistically consider different drivers and focus on the overall land-use change emissions impacts, while ILUC assessments focus on the individual driver (biofuel production) and trace its emission impacts across time and space. Although ILUC and carbon leakage assessments commonly focus on quantifying emissions, land-use change impacts in general of course also include other environmental or socio-economic challenges, such as biodiversity loss, water and soil impacts, or social rights issues. In general, any policy seeking to reduce land-use change emissions can only be effective if the driving forces behind the process are identified and addressed (Nassar et al. 2011, van Stappen et al. 2011).

4. 2 Policy forum

It is possible to identify two policy fora where the debates on carbon leakage and ILUC take place as land-based policy options; those are the climate policy and the energy policy arenas. Both debates share the GHG focus and therefore they both belong in the policy forum of the UNFCCC. However, the main discussion on ILUC happens within the energy policy forum where also energy security is embedded (e.g., Hertel et al. 2010). Carbon leakage has for more than a decade been a topic in international climate policy discussions (e.g., IPCC 2000), while ILUC is a relatively recent issue associated with bioenergy. Interestingly, when ILUC is discussed within climate policy (such as the UNFCCC), it is often described as carbon leakage (e.g., Eggert and Greaker 2012). One main difference is that carbon leakage is either regarded as a local problem at project scale, as in the IPCC definition of carbon leakage, or considered at national scale as in the current policy text on REDD+ (see UNFCCC 2009); while ILUC often has a more prominent regional context, such as in the case of the EU and its work on RED or the US's biofuel policies (e.g., Searchinger et al. 2008). The latter implies that ILUC is considered on all geographical scales, from within countries (i.e., national level) to between countries (i.e., regional and international level); whereas international carbon leakage is beyond the scope of IPCC emissions accounting guidelines.

4.3 Commodity, actors in the debate and liability for the emissions

In addition to the policy forum described above, other differences lie in the commodity and the actors involved in the two debates (Table 2). In the early stage of REDD+ and the associated carbon leakage debate the focus was the saved carbon that would generate a carbon credit. The actors driving the debate were mainly technical experts and academia, and only to a limited degree UNFCCC negotiators. Even though the evolution of REDD+ has made its stakes expand beyond pure carbon savings (e.g., through the development of safeguards for biodiversity and indigenous peoples or general forest policy) the main commodity is still the carbon saved within the forest ecosystem - or in the carbon leakage situation, the emitted carbon. The liability of emissions from carbon leakage has in the project-based mechanisms of the past been in the hands of the project developer, or producer of the carbon credit (e.g., in the CDM or under voluntary market standards). Leakage emissions are deducted from the overall emission reduction achievements before the carbon credits are issued, thus reflecting producer liability in an adjusted project emissions balance. In a future national-scale REDD+ mechanism, the liability will most likely be with the seller nations that account for their emissions balances including leakage in a national monitoring and reporting system (UNFCCC 2009).

Table 2 near here

For bioenergy production, the main commodity produced has always been the feedstock for biofuel production. A market for biofuels existed even before the ILUC issue came up in 2008. Critical ILUC discussions were initiated from market-external actors such as academia and media, and have influenced the consumer side much more than the producer side. In consequence, ILUC emissions enter the biofuel emissions balance as separate item, declared as additional information that complements the conventional life-cycle emissions from the production chain. The main difference to carbon leakage is here that the liability for ILUC is not directly attached to the actual production of the fuel (and the emission) but is up to the willingness and policy regulations of the consumer nation; which means that ILUC will mostly be addressed at government or national level in the consumer countries. Like that, fuel standards in particular markets define whether and how ILUC is accounted for. The US Low Carbon Fuel Standard for instance prescribes the use of ILUC emission factors, which are applied on the demand side, meaning that the users / consumers of the biofuel have to demonstrate emission reductions, and not the producer/seller of that fuel (ARB 2012) (see section on methods below). This ILUC-factor declaration is meant as a piece of information for the sake of the consumers, which here are not individuals but rather nations (US) or regions (EU).

As a consequence, for an actor such as a policy maker or individual consumer, the commodity within ILUC is closely connected to behavior (e.g., driving a car) and it is therefore easier to see the link between behavior and an unwanted negative impact (e.g., deforestation) compared to carbon leakage, which is perceived as an issue of producer responsibility. Due to the behavioral link between biofuel and driving in combination with the debate on biofuels as mitigation option for climate change, the ILUC issue has been more visible in the public debate and has reached greater public awareness than carbon leakage from forest conservation interventions.

5. Methodological comparative analysis

The definitions of ILUC and carbon leakage imply that a causal relationship has to be demonstrated between the intervention and the land-use change effect. While local activity shifting effects can be mapped and measured on the ground, indirect market leakage and international effects are more diffuse and are difficult to monitor and quantify. In both cases the isolation of the displacement effect that clearly shows an increase in emissions due to a given intervention is often challenging (e.g., Peters 2008; Nassar et al. 2011).

Here, we take a look at the methods used to quantify within-country and international carbon leakage and ILUC, (Table 3) using a classification from Gawel and Ludwig (2011) as comparative framework. Included in this section are both quantification methods and approaches to address carbon leakage or ILUC without quantifying the actual emissions. A more rigorous description of those methods and approaches can be found in Henders and Ostwald (2012) for carbon leakage and in Gawel and Ludwig (2011) for ILUC.

5. 1 ILUC methods and approaches

Methods for the assessment of ILUC are relatively recent, and can mostly be found in scientific literature and policy documents since 2008. Gawel and Ludwig (2011) provide a comprehensive analysis of possible approaches to ILUC, which can be divided into three broad categories: 1) impact-related methods, 2) product assignment strategies and 3) general governance approaches (Table 3). In addition to technical quantification methods, Gawel and Ludwig (2011) also include policy approaches such as reducing land-use pressure through less ambitious biofuel targets.

1. *Impact-related methods* seek to make indirect effects direct by focusing on local land-use impacts of a bioenergy plantation. ILUC quantification methods in this category focus at the respective land use and map every direct land-use change (DLUC). Thus, ILUC is transformed into DLUC with biofuel production as driver behind the changes. This approach requires a detailed spatial land-use assessment or field measurements and is applicable in limited local and national circumstances. Another impact-related approach to ILUC is the use of safeguards that limit land-use change in areas with high conservation value, such as biodiversity and carbon hotspots. The safeguard approach is used in the EU biofuel sustainability criteria to prevent direct LUC and is also part of the UNFCCC REDD+ policy where the conversion of natural forests and loss of biodiversity should be avoided.

2. *Product assignment strategies* aim to internalize the ILUC effect on the emissions balance of specific bioenergy products. One option to do this is assigning an ILUC-factor to each biofuel feedstock crop, which contains information about the potential ILUC emissions per unit of energy produced and is typically expressed in weight carbon dioxide equivalent per megajoule (gCO_2eq/MJ). This approach is used in the US Low Carbon Fuel Standard (ARB 2012) and included in the present proposal to the European Parliament relating to quality and use of energy from renewable sources (European Commission 2012). The determination of ILUC factors is typically based on modeling, often using economic equilibrium models or deterministic models (Fritsche and Wiegmann 2011). Another, simpler way to set ILUC

factors is the use of generic discount values in a schematic accounting approach, which involves a symbolic emissions percentage to be added to the overall life-cycle emissions. Other strategies in this category aim to minimize ILUC through emissions bonuses for biofuels grown on degraded or contaminated lands or to label products based on their (non-quantified) risk to incur ILUC through certification systems (Miyake et al. 2012). While the former addresses biofuel producers directly, the latter leaves it to the informed consumer to minimize ILUC by purchasing low-risk biofuel products, for instance based on the “Low Indirect Impact Biofuels” methodology (LIIB 2012).

3. In addition to the above, a third category of *general governance approaches* relies on policies to minimize indirect land-use change, which represents a way to address rather than a method to quantify ILUC. The idea is to minimize ILUC incentives by lowering land use pressure, with policy instruments such as reduced biofuel targets and quotas, feed-in tariffs with guarantied prices for small-scale producers, or the promotion of second-generation biofuels that use residues and biowaste (e.g. Witcover et al. 2013). Another option is reporting requirements that can create information for policy makers and the public and hence can be the basis for future decisions.

While the US Low Carbon Fuel Standard relies on fixed ILUC factors to account for indirect land-use effects from biofuel production, the EU Renewable Energy Directive suggests including a mix of the above options. It combines the use of ILUC factors for biofuel crops (European Commission 2012) with governance approaches, limiting the use of land-based biofuels to 5 % while promoting second-generation feedstock.

5. 2 Carbon leakage methods

Main sources for carbon leakage quantification methods are the different carbon accounting guidelines and scientific literature. Based on these, Henders and Ostwald (2012) identified nine different quantification approaches for carbon leakage that address either primary (6) or secondary (3) leakage, distinguished by the respective drivers behind displacement processes. The majority of methods address primary leakage that involves a direct shift of pre-project activities from the project area to the surroundings by local deforestation agents.

1. Using the above-described classification by Gawel and Ludwig (2011), most of the methods to quantify primary leakage would belong in the first category of *impact-related methods.* As such, they often involve direct measurements in the field to map land-use displacement from the project area.
    - Methods are based either on directly monitoring logging levels of deforestation agents with legal logging licenses, or on monitoring land-use activities in a reference area around the project to see whether pre-project activities relocate to the surrounding area and cause new emissions there. These options record direct land-use changes on the ground, which corresponds to the mapping of ILUC effects in the field as described above, and accordingly allows an application at local level only. Direct monitoring methods are mainly used in the CDM and the VCS.

- A method to extend the geographical scope to the national level uses the local mapping approaches as basis and then analyses whether activities displaced from the project area all appear in the reference area, or whether parts have moved beyond to other locations in the country. As the latter is an un-identifiable process, it is conservatively accounted for by assuming it causes emissions equivalent to the average national forest carbon content. The fraction of activities relocating to remote places is determined by deducting the activities appearing within the reference area from the total activities displaced from the project area. These approaches are mainly used in CDM afforestation and reforestation projects, and in the VCS.
- Another way to make indirect impacts direct is the use of models. Modeling approaches to quantify primary leakage use for instance the probability of a land use being converted to other uses, or they apply historical adoption rates for agroforestry activities to deduct future leakage activities. Typically these approaches are found in scientific literature.
- When it comes to secondary leakage or market effects, one possible "mapping" approach is the use of detailed market assessments, where project developers have to show that key market indicators such as price and /or volumes traded have not increased due to their project activities. This requires close observation of markets and their trends over time, which can be challenging. If the assessment also covers international markets, it is possible to distinguish between leakage on national scale and the fraction that moves abroad. This approach is included in a VCS methodology.

2. *Product-assignment strategies* are slightly different in the case of carbon leakage, as the product at hand is the emission reduction in form of a carbon credit (see above). Considering net emission balances as product, we therefore place all approaches to create leakage adjustment factors in this category. These include both model-based and schematic accounting approaches in form of generic discounts.
    - Just as for ILUC, model-based discount values for market leakage are commonly quantified through econometric modeling. The general or partial equilibrium models typically used here assume an ideal condition of market equilibrium and perfect competition and from this optimize a net present value of consumer and producer surplus. While equilibrium modeling is a common leakage quantification method used in scientific literature, it is not used in the carbon market standards, which could possibly be explained by the complexity of models and the large amount of input data required.
    - Instead, the most widely used approach to market leakage in the carbon standards is the application of generic discount factors, which are based on the biomass content in the project area compared to that of a hypothetical forest area where harvesting could potentially be moving to. Depending on the difference in biomass between these a discount factor can be applied. The Verified Carbon Standard for example uses 20, 40, 70 % depending on the new area having a higher, equal or lower biomass and carbon stock. Generic discount values are also used as simplified option to address activity-shifting leakage. They are applied if a certain percentage of displacement occurs, based on measuring and monitoring the development of original land use activities in the project area. This approach is used in some voluntary carbon standards such as Carbon Fix, and in the US Climate Action Reserve (CAR). Generic discount factors address the possibility of displacement effects without requiring quantification of actual leakage impacts.

3. *General governance approaches* are not widely discussed for carbon leakage. On local level, leakage minimization strategies include the creation of alternative livelihood options for local deforestation agents, or increasing productivity of existing land uses in order to decrease local land use pressure and incentives to shift activities elsewhere (Aukland et al. 2003). Regarding international displacement, an often-cited solution is to include all countries in a REDD+ mechanism or climate agreement, which however we do not consider a feasible option. While policy texts emphasize the importance of addressing and controlling deforestation drivers (UNFCCC 2009) for minimizing leakage, the pragmatic approach taken by the UNFCCC is to exclude international leakage effects from accounting.

Table 3 below summarizes the methodological approaches described here and illustrates several overlaps between methods for ILUC and carbon leakage quantification.

Table 3 near here

6. Methodological similarities and differences

Table 3 shows that methods to quantify ILUC and carbon leakage share several common approaches. Both use direct mapping of land-use impacts in the field on local scale, safeguards, and modeling or factor approaches for large-scale market effects. While carbon leakage methods focus mainly on the technical level of quantifying emissions or factoring in potential leakage effects, ILUC approaches are somewhat broader, including incentive-approaches and policy strategies to minimize the risk for land-use change.

A first difference that emerges from the comparison is the strong focus that carbon leakage methods have on mapping impacts on the ground**,** while this approach is only briefly mentioned in the ILUC literature (Gawel and Ludwig 2011). A reason for this could be that carbon leakage methods have typically been developed for individual project activities under the CDM or in the voluntary carbon market. Methods determine the amount of leakage emissions from a local project activity, which are then deducted from the overall emission reduction achievements to reflect the net climate benefit. Therefore most methods target carbon leakage at local and national scale, while international displacement is hardly addressed. The mapping methods for primary leakage are very detailed and cover a range of different land-use activities. With this, they are able to directly attribute leakage effects to the driver, and quantify incurred leakage impacts on the ground, based on field measurements. While this ensures an advanced level of accuracy in leakage determination, the applicability of this approach is mainly local. In this, quantification methods for carbon leakage differ from ILUC methods, which commonly address international scales. This is because ILUC methods typically target diffuse market effects from large-scale biofuel policies, involving substantial changes in land use both domestically and internationally.

The main approach used in ILUC methods are therefore product assignment strategies such as the ILUC factor, applied as quantitative complement in emissions per energy unit to biofuel life-cycle emissions. This factor does not distinguish between the geographical scale of impacts and can thus be used to account for both national and international effects. The ILUC factor corresponds to average emissions from indirect land-use change from a certain biofuel crop, which is usually determined in model calculations. Like that it does not refer to actual ILUC effects incurred on the ground, but rather specifies an average, generalized impact. All recent major efforts to determine ILUC factors are based on coupled general equilibrium and biophysical models (e.g., LEITAP, FAPRI, AGLINK, see Netherlands Environmental Assessment Agency (PBL) 2010). While these allow comprehensive market assessments, they also involve large uncertainties stemming from data quality and underlying assumptions, which cause huge variations in results. One reason is that actual land-use change drivers are difficult to predict and quantify, so that all modeling exercises operate under high uncertainty of how and why land-use change processes really occur (Nassar et al. 2011). This is one of the reasons why equilibrium modeling to determine international leakage effects under the UNFCCC is seen critical by the IPCC (IPCC 2007).

With model-based ILUC factors thus involving high uncertainties, an alternative approach is the use of generic ILUC factors, which are also widely used in the voluntary carbon market and some US carbon standards. The use of risk-based generic percentages is a pragmatic approach to taking carbon leakage into account without having to quantify the effects. With this, generic discount factors account for potential leakage effects without knowing whether or not they occur. The problem here is that in reality indirect effects could be lower or higher than the applied discount factor. Nevertheless, it can be argued that model-based values incur similar uncertainties yet at a much higher level of complexity.

The overall approach to apply adjustment factors to emissions balances, both in ILUC and carbon leakage, is a way to address displacement effects that cannot be traced on the ground, which is the case with market leakage or international displacement in general. While the determination methods for discount values can be contested, their use represents a more conservative approach than the mere exclusion of international leakage effects under the UNFCCC.

In terms of general governance approaches, national biofuel policies have been established relatively recently, which is why policy options such as revision of targets or promotion of residue-based fuels are still actively discussed in order to optimize outcomes and minimize adverse effects such as ILUC. In contrast, the Kyoto Protocol and the associated leakage debate were initiated in 1997, suggesting a certain maturity of processes that allows for less flexibility in policy adjustment. While the leakage debate has resurfaced again during recent REDD+ negotiations, the conclusion was that leakage within a REDD-country would not constitute a problem in a national-scale mechanism as all displaced emissions are accounted for in national inventories (UNFCCC 2009). International leakage is beyond the scope of current carbon emissions accounting under the UNFCCC and also the voluntary carbon market (Henders and Ostwald 2012), due to the production-based accounting principle of the UNFCCC.

7. Discussion: So what does this mean?

From our assessment it is possible to conclude that there are more similarities than differences between the debates around carbon leakage and ILUC. This is due to a shared concept of land-use displacement and a common theoretical base where the same sort of definition is used.

A conclusion from the comparative assessment of methods is that tracing and mapping of land-use changes on the ground is best suited for accurate quantification of land-use displacement effects. While carbon methods are very advanced in providing detailed methods to monitor activity-shifting leakage, ILUC approaches very rarely use this method. A main disadvantage is the local applicability of mapping methods, which can only be used in close surroundings of a biofuel or carbon land-use project. A broader applicability of this approach, also in the context of ILUC, would require the monitoring and accounting of all land uses on national scale. Although this seems not feasible at present (Fritsche and Wiegmann 2011), the concept of REALU (reducing emission from all land uses) is discussed within the broader climate policy debate on land-based mitigation options (see e.g., van Noordwijk et al. 2009).

Methods in the product assignment category that quantify international emissions displacement effects face the ILUC dilemma (Gawel and Ludwig 2011) or the chicken-and-egg situation (Nassar et al. 2011)**,** which is to say that the proposed methods are unsatisfactory when it comes to determining actual displacement emissions incurred, as equilibrium modeling or generic discount values used to account for un-measurable effects involve high uncertainties. The question is, is that a reason not to use them at all, or should values be used that run the risk of being inaccurate, but at least somehow account for potential effects? The main difference we find between ILUC and carbon leakage is the reaction to this dilemma in the context of quantifying international effects. The UNFCCC, one of the dominating forums where carbon leakage is relevant, effectively ignores the problem due to the uncertainties involved in equilibrium-based model estimates and its focus on territorial emissions. Some actors within the ILUC debate assume that using ILUC factors is reasonable to at least acknowledge that displacement emissions exist, even if the actual values applied are too high or too low in reality. Seen from a climate perspective, the UNFCCC approach will definitely underestimate leakage emissions, while the ILUC approach might yield inaccurate values but is more conservative in terms of environmental integrity.

The reasons explaining why two so similar issues could be discussed in such an isolated way are of course interesting. The explanation can most likely be found in different configurations of the markets and policy processes relating to ILUC and carbon leakage:

In the case of REDD+ the sellers of the carbon credits will be governments of countries that participate in the mechanism, considering that credits have to be accounted at national level. In the case of biofuels the sellers are independent companies that produce or process biofuel feedstock. This makes a great difference in terms of governance. Modalities and accounting methods for leakage from REDD+ are governed by a UN process in which all the participants are nations; in ILUC, the producers/sellers are not part of a single negotiating system. While some of them may be members of Round Tables there is no centrally coordinated process and binding policy forum, which is directly responsible for international rules on biofuel production. Individual nations have no obligations to enforce rules on their producers, which is why any conditions or modalities regarding accounting for ILUC can only be enforced by buyers (individually or collectively, e.g., in the case of a European directive).

A consequence of this set-up is the distribution of liability for ILUC and carbon leakage emissions, which is linked to the underlying accounting principles of producer (carbon leakage) and consumer (ILUC) responsibility. The territorial-based ‘polluter-pays’ principle is used in many environmental treaties such as the UNFCCC and the Kyoto Protocol, and implies that all environmental impacts related to domestic production activities are allocated to the producer (Rothmann 1998). This is also the case in the accounting of carbon leakage emissions under the UNFCCC; in addition to quantification uncertainties this has been another central argument to exclude international leakage emissions from the accounting scope. As the UNFCCC covers not only the land-use sector (i.e., forestry and agriculture) but another 13 mainly industrial sectors, accounting for international leakage would be required in all those sectors. This would be a major undertaking that might face competitiveness concerns and resistance, for example from industry. It is possible to link domestic producers to displacement processes within their own country, but how can they be made responsible for emissions relocating to other countries?

The consumption-based principle addresses exactly this question, by allocating responsibility for environmental impacts, regardless of where they occur, to the consumer nation (for more detailed literature on this issue, see e.g., Rothmann 1998; Munksgaard and Pedersen 2001; Peters 2008). This principle is reflected in ILUC accounting, where consumer governments such as the US or EU assume responsibility for emissions by trying to minimize ILUC impacts of land-use change through sustainable development criteria and/or ILUC factors. This process could be facilitated by the fact that ILUC from bioenergy involves a clear definition of scope, which is limited to the land-use sector. Accordingly, the policy approach to ILUC is more focused on a product aiming to replace fossil fuels as a mitigation option, rather than reforming accounting rules for 14 different emission sectors.

Another reason for the differences within these two debates could be public interest and the presence of a lobby in the case of ILUC. Due to the fact that bioenergy is a commodity in demand, ILUC has a market component that makes it different from carbon leakage, which is to a higher degree a problem of environmental integrity. The market interest creates lobby activities (van Stappen 2011). In addition, bioenergy and biofuels are products that are clearly and easily understood by the public and associated with common behavior that everyone can relate to, such as driving a car. Due to this understandable market product in combination with a lobby, ILUC issues achieve a greater level of public awareness than carbon leakage, which is more diffuse and usually discussed at expert-level.

The main question arising from this comparison is whether these two processes have the potential to use synergies and learn from each other in the optimization of climate benefits and minimization of adverse indirect effects. In this context the ILUC approaches can be regarded as more beneficial from a climate perspective. On one hand, the policy process is flexible enough to allow for adjustments when adverse effects are demonstrated, such as the recent shift in EU biofuel policy towards second-generation biofuels instead of land-based crops inducing leakage, and a revision of the 10 % target (European Commission 2012). One the other hand, faced with high uncertainties of model results, accounting for ILUC is not abandoned but applied in a conservative accounting approach. Emission accounting frameworks, especially under the UNFCCC appear much less flexible in policy adjustments when faced with high estimates of international leakage effects. While methods to determine local displacement are more sophisticated within the UNFCCC, the solution taken to international displacement is more pragmatic than environmentally integer.

While the difference in liability for displacement emissions might be linked to the set-up of the policy forum, the choice of consumption- or production-based accounting principles seems decisive in addressing international displacement processes. The GHG accounting principle that holds producer nations liable for domestic emissions omits that the demand causing deforestation and indirect land-use change is global and so is the trade. The partial coverage of the Kyoto Protocol and any future climate treaties encourages displacement effects to countries without emission reduction targets, and the production-based principle does not foresee to account for these displaced emissions. We therefore argue that the consumer perspective taken by the ILUC approach allows for higher environmental integrity by taking international displacement effects into account. Although the institutional conditions surrounding the two concepts vary, it might be beneficial in order to optimize climate benefits of climate mitigation action to consider the use of consumer-based accounting methods alongside the traditional territorial approaches, to quantify the magnitude of leakage emissions. In this, the described methods to account for ILUC could be a way forward to quantify the magnitude of leakage emissions, albeit without necessarily allocating all emissions to the consumer nations or buyers of REDD credits. The allocation of liability could happen in a second step; options include a) full allocation to the producer, b) to the consumer, or c) shared responsibility based on quotas agreed upon in climate policy negotiations (Lenzen et al. 2007).

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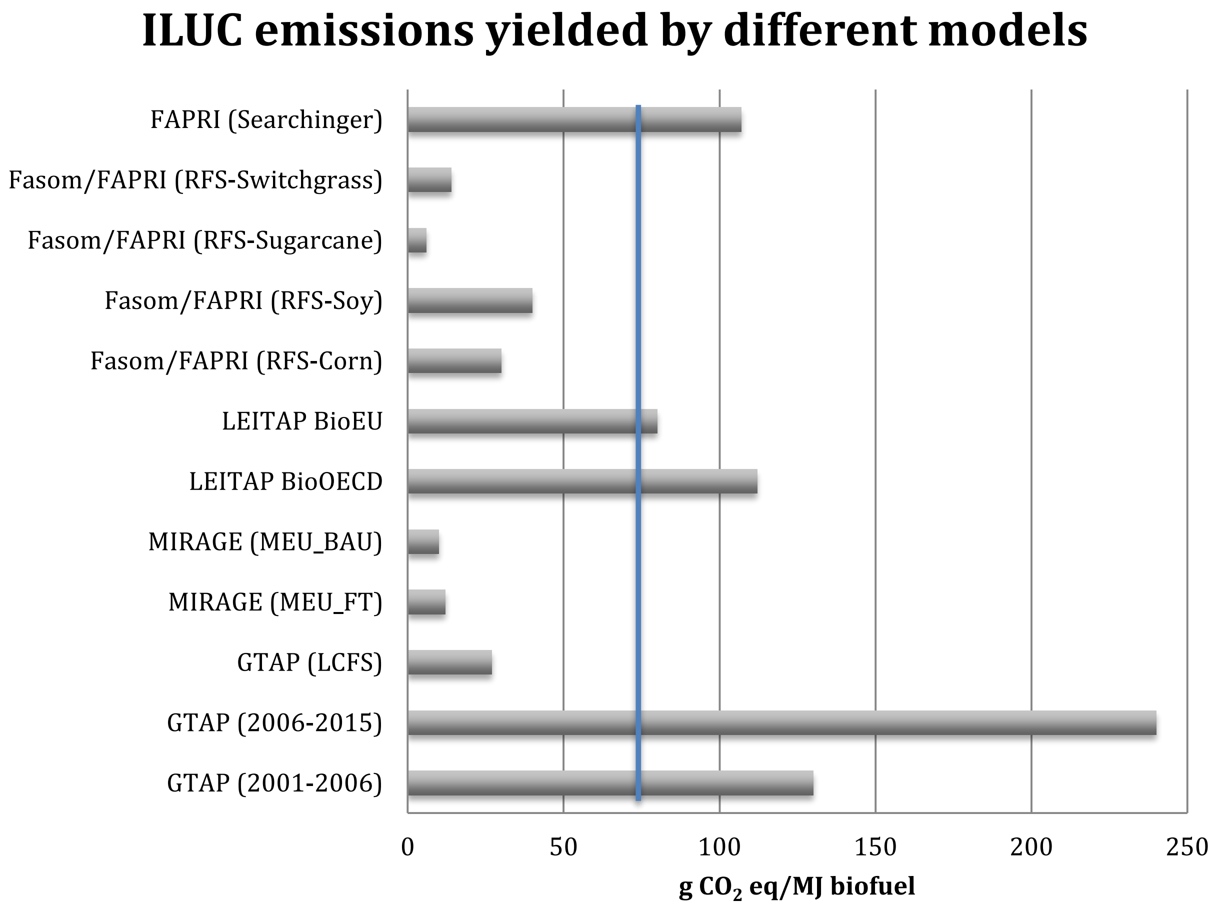

Figure 1: ILUC emissions yielded by different model scenarios excluding life-cycle emissions from biofuel production. RFS for Renewable fuel standard program; MIRAGE (MEU_FT) for EU mandate full multilateral trade liberalization; MIRAGE (MEU_BAU) for EU mandate with current trade setting; GTAP (LCFS) for Global Trade Analysis Project Low Carbon Fuel Standard. The blue line indicates the gasoline emission benchmark of 74gCO_2 eq/MJ (Wang et al. 2012). Modified from Netherlands Environmental Assessment Agency (PBL) (2010).

Table 1: Land-use change terminology used to describe similar climate change-related processes within the sector of forest conservation versus bioenergy production.

Process	**Forest conservation for climate mitigation**	**Bioenergy production**
Converting one type of land use to another, for example forest is turned into agriculture	Land-use change	Direct land-use change (DLUC)
Activity in one area is moved to another area due to change in land use, for example a grazing area is converted to sugarcane plantation and forest in another area is cleared to house the removed cattle	Direct or primary leakage	Indirect land use change (ILUC)
Activity in one area indirectly creates incentives to change land use/deforest in other areas, for example forest conservation causing reduction in timber supply increases timber price, making new deforestation profitable	Indirect or secondary leakage	Indirect land-use change (ILUC)

Table 2: Differences between carbon leakage and ILUC in terms of commodity, actors involved in the debate and liability for the emission.

	Carbon leakage	**ILUC**
Commodity	Carbon credits/emission savings from land-based activities	Bioenergy product with carbon emission from ILUC attached
Actors involved in the debate	UNFCCC negotiators, technical experts, academia	Governments (as policy makers and as consumers), technical experts, academia, Env. NGOs, media
Liability for the emission	Producer of the carbon sink or carbon emission (project developer)	Consumers' governments (such as EU or USA) of the bioenergy

Table 3: Comparing quantification methods and policy approaches used for carbon leakage and ILUC, based on three main categories introduced by Gawel and Ludwig (2011).

	Categories of approaches		
	Impact-related: make indirect effects direct	**Product assignment: Discount factor to specific crops and products**	**General governance: Policies to minimize displacement pressure**
ILUC	- **Mapping** direct land-use changes - **Safeguards:** Exclusion of biodiversity and carbon hotspots	- **Discount factors** reflecting ILUC emissions: i. Either model-based (equilibrium, deterministic models), or ii. Schematic accounting through generic ILUC factor - **Bonus system**, for example for use of degraded land - **Risk-label** attached to bioenergy products through certifications	- **Lowering pressure**: Reduce targets, promote second generation biofuels from residues, increase efficiency of use - **Reporting requirements**: Influence policy makers for adjustment of policy
Carbon leakage	- **Mapping and monitoring** of deforestation agents and land-use changes in reference area; probability and deterministic models for activity shifting - **Safeguards**: Exclusion of natural forest conversion	- **Discount factors** adjusting emission reductions for leakage i. Model-based accounting with general or partial equilibrium models for market leakage, or ii. Generic leakage factors	- **Inclusion of all countries** in a global climate agreement - **Addressing and controlling** deforestation drivers considered best for minimizing leakage - UNFCCC policy approach to international leakage: **Exclude from accounting**