European Commission Indirect Land Use Change (ILUC) public consultation

Imperial College London, LCA works Submission

Dr Jeremy Woods, Mr Mark Akhurst, Ms Nicole Kalas, Dr Richard Murphy, Prof Nilay Shah, and Prof Richard Templer

Imperial College London, LCA works welcomes the opportunity to respond to the questions presented to stakeholders on the results of the recent Indirect Land Use Change (ILUC) modelling analyses. ILUC is will remain a very complex issue with scientific consensus on its impacts unlikely to be reached within this decade and we welcome the leadership position the European Commission (EC) is taking on this topic. We have included our responses to the questions in the following pages but we would like to begin by making some general observations:

- The carbon stock change and biodiversity impacts of land use change are likely to be critically important components in delivering sustainable supplies of food, energy and materials to current and future generations. We have been investigating these issues since the early 1990s and trying to highlight its importance since that time, e.g. see Woods and Hall, 1994.
- Imperial College London, LCA works recognises the need to understand fully all impacts of expanding biofuels production, including all land use impacts. However, after careful analysis of the modelling work commissioned by the EC (IFPRI, 2010; JRC, 2010; JRC-IPTS, 2010), we conclude that the global and partial equilibrium models employed fail to adequately assess the carbon and other greenhouse gas (GHG) impacts of ILUC associated with expanded biofuel production.
- The modelling analyses carried out in the different studies were unable to reach consistent results. For example, the ILUC impacts calculated by the different modelling approaches vary by up to three orders of magnitude in some cases. Also, in terms of physical ILUC there is an enormous range in projected gross and net land demand(s) per unit of biofuel produced. From the data presented in the three EC modelling studies we calculate this range to be 2.4 to 47.6 Mha/EJ of biofuel delivered.
  The following are examples of some of the factors that may explain this wide variation in the results:
  - The current models fail to consider all the relevant drivers of land use and land use change.
    - The models suffer from numerous inconsistencies in underlying assumptions and uncertainty of input data. For example, projected transport energy demand in 2020 for the EU varies from 300 Mtoe to 380 Mtoe.
  - All of the models face the challenge that their future predictions are based on historic trends which, in a very dynamic world, cannot be guaranteed to hold good in the future, for example:
    - How to account for future crop yield increases when the data and modalities within the models are based on historic data gathered in a world with very different market conditions i.e., before the recent dramatic emergence of the developing nations, and before biofuels had reached such significant market penetrations?
    - How to include the impact of technological advancement, which, as with yield increases will be driven harder in the future as a result of global change and growing biofuel markets. Extensive work carried out at Imperial College and others has demonstrated the potential for advanced / 2nd generation (2G) biofuels to offer improved GHG savings at lower costs, with dramatically improved biofuel yields per hectare of land (Woods et al, 2009, 2010; Murphy et al, 2010; Smith et al, 2010; Lovett et al, 2009; Dunnett et al, 2008; Woods and Hall, 1994).
    - How to allow for future changes in trade and fiscal policies?
    - How to allow for the impacts of climate change on potential crop yields and growing patterns?

- It is important to understand that any bioenergy policy will play out in a highly dynamic environment and are themselves drivers of change through 'feedback effect' on aspects such as yield increases, agricultural efficiency, nutrient input and capture optimisation, carbon stock levels in agricultural land, etc. Any attempt at modelling these interactions will therefore necessarily result in wide ranges of uncertainty. All of the models employed in the EC studies attempt to simulate the interactions between new biofuels production chains and the dynamic global system. The ILUC impact obtained in this modelling exercise are therefore best understood as a *function of this interaction* and *not a defined property* of biofuel production *per se*. Unless this dynamic interaction can be accurately represented in the models, it will not be possible to consistently and reliably assess the GHG impacts of biofuel-induced ILUC in the near- to medium-term future.
- In our view, if biofuels are to make a material contribution to meeting transport fuel energy demand with significant GHG savings by 2020 and beyond, then advanced biofuels (e.g., ethanol from lignocellulosic feedstocks) will need to make a major contribution. Most of the modelling approaches used either do not include advanced biofuels within the models or deal with 2G biofuels in very different, but always inadequate ways. We believe this to be a very serious deficiency of the modelling, leading to a partial and distorted assessment of the future impact of biofuels expansion on ILUC.
- At Imperial College, we have carried out extensive work to explore the potential of land and land use to make a contribution to controlling the levels of GHGs in the atmosphere (Woods et al, 2009; Murphy et al, 2010; Dunnett et al, 2008; Woods and Hall, 1994). We believe that there is enormous and beneficial potential in this area, through more effective land management, improved crop yields (e.g., through improved varieties and better farming practices), and improved sustainability and conservation practices. We are extremely concerned that the disproportionate amount of attention currently directed at ILUC will divert us from more fully understanding and implementing the opportunities that exist for integrated / productive land use to contribute in this area.

Imperial College London, LCA^works responses to the questions posed in the ILUC consultation

Question 1 - Do you consider that the analytical work referred to above, and/or other analytical work in this field, provides a good basis for determining how significant indirect land use change resulting from the production of biofuels is?

No. Our assessment is that the models reviewed within the scope of this analysis proved to be inadequate in determining ILUC impacts associated with expanded biofuel production in a robust and transparent manner. Some of the reasons for this are highlighted below.

- The results of the modelling show, to varying degrees, that an increase in land use for agriculture will result from the expanded biofuel targets when compared with the counterfactual (i.e., keeping biofuels at current incorporation levels, or allowing market-driven expansion). For the EU27, the results tend to show that land use for arable crop production will continue to decline, even with the expanded biofuels targets, but by a smaller amount than would otherwise be the case. These results need to be taken in the context of recent global trends in land use change, as driven by other factors. Table 1 illustrates the total area of global arable land and annual variations in arable crop land between 2000 and 2007.

Table 1. Global arable land and annual variation (Mha) 2000-2007

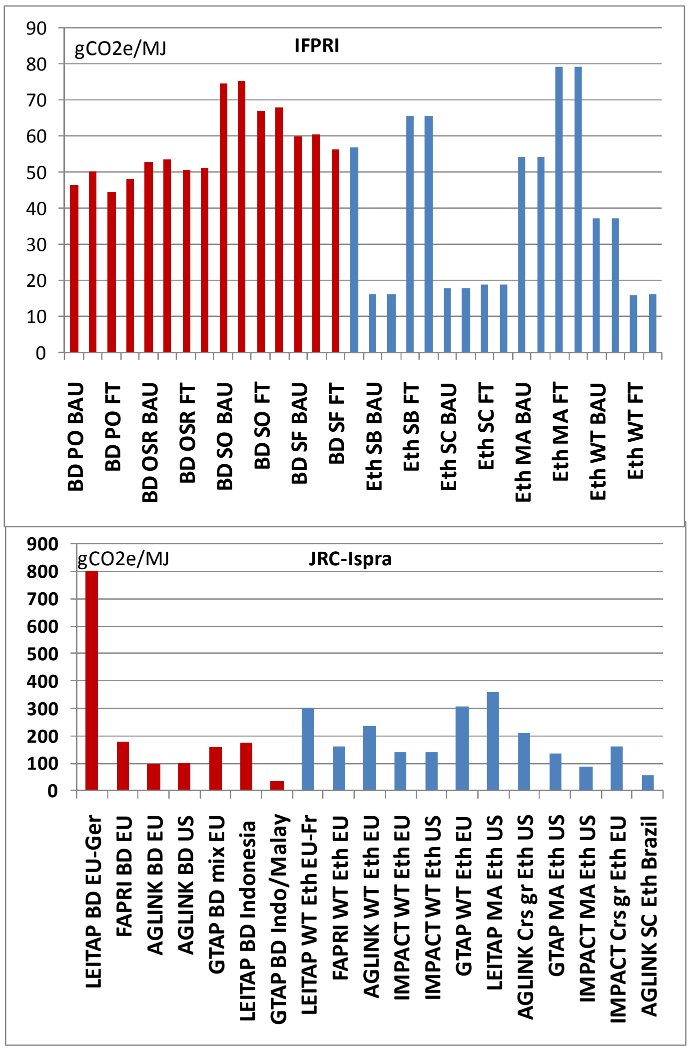
Year	Total arable land (Mha)	Δ fr. previous year (Mha)
2000	1,397.96	--
2001	1,398.03	0.07
2002	1,396.27	-1.76
2003	1,402.60	6.33
2004	1,405.83	3.23
2005	1,412.14	6.31
2006	1,411.72	-0.43

2007	1,411.12	-0.60

Source: FAOStats, 2010

- The models are not able to predict where land use change will occur and what types of land are likely to be converted in response to increased biofuel demand. This is because where the models do calculate GHG impacts associated with soil emissions, these are always based on historic land use patterns in the country / region concerned. There is no guarantee that future land use change will follow the same patterns.
- As well as the significant level of uncertainty associated with the results, another concern is the range of results emerging from the different models. Figure 1 shows the range of GHG impacts represented by the modelling results.

Figure 1. GHG Impacts (g CO_2e/MJ) from IFPRI and JRC-Ispra Studies by model and feedstock



Source: adapted from IFPRI, 2010; JRC-Ispra, 2010

- The reasons for the wide variation in results between the different modelling studies include a combination of factors:
  - Differences between the scenarios modelled, i.e.
    - forecasted transport fuel demand in 2020
    - amounts of biofuels assumed will be blended
    - the amounts of 2G biofuels in the fuel mix

    - policy assumptions
    - etc.
  - Differences in the counterfactual scenarios – some models look at the change in biofuels from current levels (approx. 3.3% market penetration in Europe), whilst others look at the difference the Renewable Energy Directive (RED) will make compared with biofuel expansion as driven by market forces.
  - Differences in the structures of the models, including differences in geographic representation and segmentation, representation of technological advancement and crop yield growth, handling of global trade uncertainties, etc.
  - Differences in key inputs to the different models (e.g., amounts of land currently used for different crops, current commodity prices, market elasticities, crop yields and biofuel conversion yields etc).
  - Differences in treatment of co-products, including the degree of disaggregation of co-product protein content.
  - Different assumptions for modeling the types of land implicated by ILUC
  - Differences in assumptions and methods for modeling carbon impacts of ILUC.
- As suggested in the JRC-Ispra analysis of six models for two EU27 scenarios (marginal ethanol and marginal biodiesel), the values of critical parameters calculated within the different models can vary by one or two orders of magnitude between the models. Variences in the key findings from this study include:
  - Generally good agreement between models in feedstock requirements per toe biofuel.
  - The fraction of feedstocks saved as a result of lower food and and animal feed consumption vary from 0.5% to 59% for the different models (savings in ILUC as a result of induced lower food consumption).
  - The fraction of feedstock saved by co-product utilitisation vary from small savings for the LEITAP model to savings around 50% of the potential ILUC for the GTAP model.
  - The fraction of increased production attributable to yield change (the CARD-FAPRI model reported a 22% contribution of yield change to EU wheat feedstock production, whilst the AGLINK-COSIMO model reported a 41% change).
  - The ratio of average crop yield to frontier crop yield (the GTAP model assumed a ratio of 0.66 whereas the AGLINK-COSIMO and IFPRI-IMPACT models assumed a ratio of 1 -indicating no change).
- It is therefore not surprising that the overall modeling results cover such a wide range of outcomes. These observations are further evidence that global and partial equilibrium modeling is not yet at a sufficient stage of development to be able to yield consistent predictions of ILUC relating to biofuel expansion.
- Further work is required to harmonize existing global and partial equilibrium models in terms of the way they handle key elements such as crop yields, use of biofuel co-products, technological development, policy and trade uncertainty and other factors.
- In terms of specifically modelling the ILUC impacts of biofuel production, standardization is also required of the key input parameters, including, but not limited to, future transport fuel demand, biofuel incorporation levels in the future, impact of advanced, 2G biofuels, amounts and quality of biofuel production co-products and their displacement values for other commodities.
- It is important to recognize that the most significant uncertainty facing the modelling is that the environment in which any bioenergy policy will play out will be dynamic. All of the models rely upon modelling the interaction between the new biofuels production value chain and the dynamic global

system. The ILUC impact is a factor of this interaction and not of the biofuel. To an extent, even a successful harmonization of the different models, taking into account all the factors described above will still not fully address this issue.

Question 2 - On the basis of the available evidence, do you think that EU action is needed to address indirect land use change?

Yes. We recognise that the EC wishes to support the expansion of biofuels as a means for improving the sustainability of transportation in Europe and as a means of reducing GHG emissions. In this respect, it is critical that the Commission establishes that biofuel expansion is being carried out in a sustainable and GHG efficient manner.

- Although the global and partial equilibrium modelling carried out to date does not provide a sound basis for calibrating the ILUC impacts of European biofuels expansion, it is likely that, without adequate policies in place, that this expansion may create land use impacts of varying degrees elsewhere in the world. It is therefore important that the EC considers carefully which policy responses are necessary to minimise any indirect land use impacts of EU biofuels expansion.
- As mentioned above (see response to Question 1), ILUC factors based on the results of currently available global or partial equilibrium modelling are very unlikely to be an effective approach, because:
    - ILUC factors as currently proposed, do not adequately address the carbon stock and GHG impacts associated with the increased production of biofuels.
    - The studies commissioned by the EC vary by orders of magnitude in their assessment and modelling outputs. They are therefore inadequate tools for establishing robust and transparent accounting methods to calibrate ILUC.
    - The more-or-less exclusive focussing on ILUC poses a serious risk of overlooking integrated land use management.
- LCA^works has identified a range of potentially effective and pragmatic measures which the EC could implement to reduce risks from ILUC. We describe them in our answer to Question 4 below.

Question 3 - If action is to be taken, and if it is to have the effect of encouraging greater use of some categories of biofuel and/or less use of other categories of biofuel than would otherwise be the case, it would be necessary to identify these categories of biofuel on the basis of the analytical work. As such, do you think it is possible to draw sufficiently reliable conclusions on whether ILUC impacts of biofuels vary according to:

- ***feedstock type?***
- ***geographical location?***
- ***land management?***

As stated elsewhere in this submission, Imperial College London, LCA^works, view is that sufficiently reliable conclusions cannot be drawn from the global or partial equilibrium modeling carried out to date. Furthermore, due to the inherent weaknesses in this type of model for modelling ILUC induced by biofuel expansion, as outlined above, it is unlikely that this type of modelling will, in the near or medium term future, offer a reliable basis for discriminating between different biofuel feedstocks on the basis of ILUC potential.

On the specific categories, we would like to offer the following suggestions on the specific categories:

1. Feedstock type

- With the exception of wastes and residues from existing food/feed crops (e.g., straw, stover), all biofuel feedstocks will require land for their production step. Therefore it is important that feedstocks with the highest outputs per unit area, after taking into account co-product utilisation, be selected. Currently these include:

- Brazilian sugarcane (for ethanol production)
- Lignocellulosic crops (e.g., energy cane and switch grass for ethanol production)
- Some grain crops that show good GHG performance and provide additional benefits from co-products (e.g, wheat or maize for ethanol production where the co-products provide valuable animal feed protein)
- Palm oil (for biodiesel production, possibly through the hydrogenation processing route). However, ILUC risks for palm oil are currently thought to be significantly higher than for the other crops, and so very careful management would be required to ensure sustainable production. In particular, because global demand for palm oil for non-fuel uses is expanding so quickly, it is very difficult to guarantee that new sources of palm oil (as would be required for expanded palm oil biodiesel production) could be sourced from non-converted land. To harness the strong yield potential of palm oil production whilst ensuring protection of natural lands (such as tropical forests and peatlands), careful land use planning would be required, to ensure that palm oil expansion takes place at the expense of less productive land use and not forest.

▪ These feedstocks can all be produced at scale and if managed carefully, with the appropriate guiding policies, can be produced sustainably and offer good GHG savings, particularly lignocellulosic crops. In addition, crops which offer a strong synergy with these or food crops grown in a region could provide an important input to biofuel feedstock production. For example, in Europe break crops are grown in rotation with the major cereal and coarse grain crops for the purpose of soil nitrogen fixing, and soil health including the control of pests. Where the break crop can be chosen to provide effective use of the land for biofuel feedstock production (e.g., as in the case of rape seed production, as a feedstock for rape methyl ester biodiesel production), then this offers an effective use of land resources, as long as other break crops which are displaced do not take up a greater area of land to produce elsewhere, if these crops are in demand.

▪ An important priority for all feedstocks is yield. Feedstocks producing high biomass yields will optimize land use and therefore minimize any potential ILUC impacts. In some circumstances, driving higher yields through higher inputs (e.g., of fertilisers) can lead to higher emissions and environmental impacts elsewhere in the biofuel chain. Therefore, wherever possible, higher yields should be driven by improved technology and farming practices, and/or by a progression to advanced biofuels (e.g., LC ethanol) which can produce higher biofuel yields per hectare with lower or shared (in the case of crop residues) inputs of fertiliser and irrigation.

2. Geographical location

▪ EU agriculture has a strong position in the provision of agricultural commodities assured under globally recognised standards. Implementation of such standards across a wider range of EU arable production in future and/or to an increased standard, would be achievable. Therefore, the deployment of an increasing share of EU biofuels, generated from EU cereals, oilseeds, lignocellulosic energy crops and renewable wastes, would help to mitigate the risks of adverse sustainability impacts from biofuels expansion.

▪ Imperial College London, LCA^{works} has carried out work for the UK Renewable Energy Association which shows that with the right supporting policies, the EU has the potential to produce up to 80% of its biofuel demand to 2020 through domestic production using domestically grown feedstocks (Imperial College London, LCA^{works}, 2009.)

▪ EU produced biofuels could enhance energy supply security, contribute up to 80% of the 2020 EU Renewable Energy Directive transport fuel targets whilst offering competitive GHG savings and create minimal environmental and ILUC impacts (Imperial College London, LCA^{works}, 2009). Meanwhile, advanced biofuels will offer potentially even greater land use efficiency, better GHG benefits , accompanied by a range of environmental benefits (e.g., landfill reduction, enhanced biodiversity and watershed management).

- Where the balance of biofuel supply needs to be imported, then the lowest risk sources (in terms of ILUC impacts) are likely to be from world regions where there are strong land use laws and where there is confidence that these laws are being properly enforced.

3. Land management

- Promoting higher crop yields on land used for biofuel feedstock production will help to reduce the amount of land needed for biofuel expansion. Good land management is one component of the actions required to increase crop yields, along with higher or better targeted inputs of (e.g., fertilisers and irrigation) and improved technology and crop varieties. Moreover, it is to be expected that the improved land management techniques and practices developed and applied for biofuel feedstock land could be deployed on a wider basis and these increases in yields on other (or potentially most) arable land leading to a 'system wide' improvement in sustainable land management for food, feed, fibre, and renewable energy.
- Biofuel feedstocks grown on land currently not used for production for food, feed or fibre have a much lower, or very low risk, of causing land displacement elsewhere and are therefore constitute low risk options for biofuel expansion. The Brazilian Sugarcane Industry Association, UNICA, estimates that there are between 25 and 35 million hectares of degraded pasture land in Brazil alone, with very low below-ground carbon stocks (UNICA, 2008). Using this for well managed sugarcane cultivation could help sequester carbon back into the soil (since sugarcane is a perennial root crop). At current rates of production (6000 litres/hectare/year, or 4000 litres gasoline equivalent/year), this degraded pasture land could produce about 100 billion litres of gasoline-equivalent ethanol/year, theoretically displacing about 25 billion gallons/year of gasoline. This alone is almost 20% of current US gasoline demand and almost 8% of current global gasoline demand.
- Support the accelerated development of 2G biofuels which have the potential to offer improved GHG savings at lower costs, and improved biofuel yields per hectare of land.
- Generally, promoting the cultivation of biofuel feedstocks which, as well as producing high biomass yields, also store carbon below ground, through their root systems, would help to improve the GHG saving potential of biofuels and offset any ILUC impacts. Perennial crops such as grasses, SRC crops and sugarcane all have the potential to maintain high carbon in soils.
- Promote technological advances, which can help reduce land demand and so free up land for alternative uses other than food/feed/fibre (e.g., in the EU arable land is being withdrawn from production despite the concerns expressed about global food supplies/prices, etc.).
- Supporting the acceleration of rural development, through or in combination with technology transfer for improved land use management, is likely to make a strong impact on slowing ILUC. Research suggests that rural development and improving land use practices are essential in slowing down the expansion of agricultural land use. Incentivising an increase in investment and technology transfer through the expansion of the biofuels industry could and should play a strong part in facilitating an acceleration in rural development and improved practices in productive and sustainable management of land.

Question 4 - If so, please say which, and indicate the evidence used to reach your conclusion.
Based on your responses to the above questions, what course of action do you think appropriate?

1. ***Take no action for the time being, while monitoring impacts including trends in certain key parameters and, if appropriate, proposing corrective action at a later date. Please say how the monitoring should be done and what these parameters should be.***
2. ***Take action by encouraging greater use of some categories of biofuel***
3. ***Take action by discouraging the use of some categories of biofuel***

1. Imperial College London, LCA^{works} believes that action is needed now and over the longer term to help ensure that any unwanted indirect land use impacts of the EU's planned biofuels expansion are minimized. However, we strongly believe that any action based upon ILUC factors, derived from global or partial equilibrium modelling will be ineffective and could pose an a significant and unnecessary barrier to the further development of a sustainable and 'GHG positive' biofuels industry. This is highly undesirable, because the biofuels industry has the potential to reduce GHG emissions, whilst performing several other valuable roles, including supporting development (which in turn would tend to slow unwanted land conversion), accelerating technology transfer, and potentially boosting crop yields across the entire ararable sector. It could also direct attention away from from the enourmous potential of better land use management for mitigating GHG emissions and resulting climate change.

The Commission should take a number of steps to begin to manage any risk of ILUC effectively:

a. Immediate actions

- Ensure an effective set of sustainability criteria are implemented in countries wishing to supply biofuels to European markets. The sustainability criteria should provide effective protection for environmentally sensitive and high carbon stock areas – an important first step in mitigating land use effects from biofuel, agricultural, or other land use expansion.
- Reward / incentivise those feedstocks which may by a variety of assessment approaches be considered to present lower risks of ILUC and which can demonstrate measures aimed at reducing ILUC risks.
- Promote the better understanding of the use of co-products in situations where the maximum land use benefits would accrue. For example, use of protein-rich co-products such as seed cakes and distillers dried grains with solubles (DDGS) can displace imported protein animal feed with high land use implications. Optimising this effect would minimise the overall effects of biofuel expansion on land use.
- Support technology transfer to and rural development within those areas internationally that may be threatened by ILUC effects of biofuel expansion. Research shows that rural development and improving land use practices are essential in slowing down the expansion of agricultural land use. Incentivising an increase in investment and technology transfer through the expansion of the biofuels industry would play a strong part in facilitating an acceleration in rural development and land use practice improvements.
- Recognise and reward integrated land management approaches.
- Promote effective conservation of high carbon stocks.

b. Medium to long-term

- Accelerate the commercial competitiveness of advanced biofuels, which would enable improved land use efficiency, lower use of other resources (such as water and fertilisers) and offer improved GHG savings.
- Support improved modelling and monitoring of existing above and below ground carbon stocks. For example, the Greenergy/Ecometrica BioCarbon Tracker offers a potentially robust, accessible platform for multi-stakeholder participation in building a global map of above and below ground carbon stocks, for identifying carbon stocks at risk and for early identification of deforestation (Greenergy/Ecometrica, 2010.).

The actions that Imperial College London, LCA^works recommends in order to help mitigate potential for undesirable impacts from biofuels expansion are:

- Ensure an effective set of sustainability criteria are implemented in countries wishing to supply biofuels to European markets. The sustainability criteria would should provide effective protection for environmentally sensitive and high carbon stock areas – an important first step in mitigating land use effects from biofuel, agricultural, or other land use expansion.

- Promote international agreements that protect biodiversity and areas with high carbon stocks, and provide compensatory mechanisms for countries and/or communities to preserve such areas and adequately enforce protective land zoning regulations.
- Reward / incentivise those feedstocks which may by a variety of assessment approaches be considered to present lower risks of ILUC and which can demonstrate measures aimed at reducing ILUC risks.
- Promote more detailed and representative accounting forthe use of co-products to correctly encompass the whole biofuel/co-product system(s), including the use of crop residues in feed/food crop/residue use systems.
- Support technology transfer to, and rural development within, areas threatened by ILUC effects of biofuel, agricultural, or other land use expansion.
- Recognise and reward integrated land management approaches.
- Promote effective conservation of high carbon stocks.
- Support technical innovation in crop production and biofuel conversion.
- Accelerate the commercial competitiveness of advanced biofuels.
- Support improved monitoring and modelling of existing above and below ground carbon stocks.
- Explore use and adequacy of dedicated models.
- Explore and quantify the unintended consequences of ILUC factors.

References

Dunnett AJ, Adjiman CS, Shah N. 2008. A spatially explicit whole-system model of the lignocellulosic bioethanol supply chain: an assessment of decentralised processing potential. BIOTECHNOL BIOFUELS, 2008, Vol:1, ISSN:1754-6834.

E4Tech. 2008. A causal descriptive approach to modelling the GHG emissions associated with the indirect land use impacts of biofuels. Final Report. Authors: A Bauen, C Chudziak, K Vad, and P Watson. A study for the UK's Department for Transport. October 2008.
http://www.dft.gov.uk/pgr/roads/environment/research/biofuels [accessed 30 October 2010]

FAOSTAT. 2010. Resource Stats – Land.
Available at: http://faostat.fao.org/site/377/default.aspx#ancor [accessed 30 October 2010]

Greenergy/Ecometrica. 2010. BioCarbon Tracker.
Available at: http://biocarbontracker.com [accessed 30 October 2010]

JRC-Ispra. 2010. Indirect Land Use Change from increased biofuels demand.

JRC-IPTS. 2010. Impacts of the EU biofuel target on agricultural markets and land use: a comparative modelling assessment.

ICONE (Institute for International Trade Negotiations). 2010. An allocation methodology to assess GHG emissions associated with land use change. Final Report (September, 2010). Authors: Nassar AM, Antoniazzi LB, Moreira MR, Chiodi L, and Harfuch L.
http://www.iconebrasil.com.br/en/?actA=8&areaID=8&secaoID=73&artigoID=2107 [accessed 30 October 2010]

IFPRI, 2010. Global Trade and Environmental Impact Study of the EU Biofuels Mandate.

Imperial College London, LCA^{works}. 2009. Review of REA Biofuel Scenario Modelling. A review of UK and EU biofuel impacts modelling. Carried out for the UK Renewable Energy Association (REA).
http://www.r-e-a.net/document-library/policy/policy-briefings/091022Peer%20Review%20of%20REA%20Biofuel%20Scenario%20Modelling%20SUMMARY.pdf
[accessed 30 October 2010]

Kutas, G. 2008. Bled Strategic Forum, Panel A: From Bali to Copenhagen – Tackling climate with re-NEW-able solutions. Géraldine Kutas, International Advisor to the President, Brazilian Sugarcane Industry Association (UNICA), Bled, 1 September 2008. Promote biofuels from abandoned, degraded land.

Lovett AA, Sünnenberg GM, Richter GM, Dailey AG, Riche AB, and Karp A. Land Use Implications of Increased Biomass Production Identified by GIS-Based Suitability and Yield Mapping for Miscanthus in England. Bioenergy Res. DOI 10.1007/s12155-008-9030-x

Murphy RJ, Woods J , Black M, and McManus M. 2010. Global developments in the competition for land from bio-fuels. J. Food Policy. In press. October 2010.

Smith P, Gregory PJ, van Vuuren D, Obersteiner M, Havlík P, Rounsevell M, Woods J, Stehfest E, and Bellarby J. 2010. Competition for Land. Phil Trans R. Soc. B. (2010) 365, 2941-2957. doi:10.1098/rstb.2010.0127

Woods J, Black M, and Murphy R. 2008. Future feedstocks for biofuel systems. Pages 207-224 in R.W. Howarth and S. Bringezu (eds) Biofuels: Environmental Consequences and Interactions with Changing Land Use.

Proceedings of the Scientific Committee on Problems of the Environment (SCOPE) International Biofuels Project Rapid Assessment, 22-25 September 2008, Gummersbach Germany. Cornell University, Ithaca NY, USA. 2009. (http://cip.cornell.edu/biofuels/)

Woods J and Hall DO. 1994. BIOENERGY FOR DEVELOPMENT: Environmental & Technical Dimensions. ISBN 92-5-103449-4, FAO, Rome.