Improving the GLOBIOM model

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Ecofys, IIASA and E4tech are undertaking a study for the European Commission on the indirect land use change impact of conventional and advanced biofuels consumed in the EU. The modeling will use the GLOBIOM partial equilibrium model, developed at IIASA.

The GLOBIOM model is well suited for the purpose of modeling ILUC. However, further improvements to the model are possible and the consortium has invited stakeholders to provide input on possible improvements. This document presents in table 1 below the final selection of improvements which the modelling team currently implements.

The selected improvements are taken from a longer list of improvements based on stakeholder recommendations received during the first stakeholder consultation in November-December 2013. The consortium selected in co-operation with the project Advisory Committee the most important improvements, which were discussed with the European Commission in January 2014, with stakeholders during the second stakeholder consultation in February and again with the Commission in March.

The long list of improvements is presented in table 2. All suggestions received have been analysed by the consortium and their feasibility has been assessed by the modelling team. The items listed in the inventory in table 2 are grouped per topical area and for each suggested improvement, a rationale is given to explain what the suggestion entails. Also, all items have been assigned a level of priority ('high', 'medium' or 'low'). It should be noted that items marked with 'low' or 'medium' priority are not necessarily less important items in terms of modelling global agriculture and forestry; these markings merely means that items do not have the highest priority for the specific purpose of modeling LUC effects of EU biofuel consumption with GLOBIOM.

For each of the items a feasibility check is performed and the data requirements associated to this improvement are explained. Following this, the effort it would take the consortium to implement the items is indicated in 'effort units' that can range from 1 effort unit (easy to implement) to 10 effort units (very difficult to implement) or even for some rare cases "infeasible". A total number of 13 effort points is available to implement the improvements.

This document is published on the project website www.globiom-iluc.eu where also other information on the ILUC modelling study can be found. Questions or suggestions to the consortium can be sent to ILUC@ecofys.com

Table 1 – Final selection of improvements to GLOBIOM to be implemented

Item	Topic	Effort units
1	Represent the yield effect of removing residues from field	2
4+5	Carbon sequestered in annual and perennial and crops	1
7 + 29	Peatland emission factors + Expansion of plantations into peatland	1
8	Expand inclusion of soil organic carbon (SOC) to rest of the world	1
9	Forest regrowth and reversion time	1
11	Improve protein and energy content representation to refine co-product substitution	2
15	Include effect of multi-cropping	Addressed in baseline
21	Imperfect substitution of vegetable oils	2
24+25	Separate representation of Argentina, Indonesia, Malaysia and Ukraine	2
27	Represent unused agricultural land in Europe	Through policy scenario
34+35	Refine supply chain coefficients (oilseed crushing, ethanol production coefficients)	1
Total effort		**13**

Table 2. Full list of improvement suggestions collected during the 1st stakeholder consultation in Nov-Dec 2013

Nr	Topic	Improvement	Priority	Effort units	Advice from AC
1.	Agricultural residues	**Improve the representation of agricultural residues** *Rationale:* Residues receive a lot of attention for their potential to produce low or ILUC free biofuel. EU straw will be part of the feedstocks modelled, but their representation is simplified (co-product in oversupply). This gives high level of priority to this improvement *Feasibility/requirements:* Agricultural residues are already in the model but in oversupply in Europe. Need to: - refine residues production values (keeping sustainable removal levels) - represent all the competitive needs of residues to assess availability - represent transportation cost constraints. *Proposal for simpler solution:* Focus on the impact on yield of residue removal.	High	4 Simpler solution: 2	Advises to implement considering modelling residues is key aim of the study.
2.	Bioenergy policy	**More refined representation of US market mechanisms (RFS mandate binding/not binding, RINs, blend wall, E85).** *Rationale*: US is a big player on the biofuel market. At the same time, markets are more isolated since anti-dumping tariffs entered in force. *Feasibility/requirements:* Mandates are already represented for RFS. Some efforts needed to represent: - change in regime depending on feedstock prices (binding/not binding mandate) - blend wall constraint requires data on number of vehicles that tolerate ethanol blends >E10 RINs dynamics seems more important for short term modelling than for 10 year time-step modelling.	Medium	2	Not discussed.
3.	Bioenergy policy	**More refined representation of Brazilian ethanol-sugar market** *Rationale:* Brazil is a big player on the biofuel market. Sugar cane, one of the feedstock considered, has dynamics connected to the development of the sugar refining sector. *Feasibility/requirements:* Different levels of development are needed: - representation of the sugar refineries' flexibility in production (data required)	Medium	5	Discussed but advises not to treat as highest priority.

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		- representation of refined sugar markets and trade - representation of Brazil biofuel policy instruments			
4.	Carbon stock	**Carbon sequestered in perennial crops** *Rationale:* Influences the carbon flows related to land use change. *Feasibility/requirements:* Some standard values could be applied to palm, sugar cane, and other perennials of interest. Taking into account the age of plantations would increase the level of effort.	High	1	Advises to implement. Combine with 5. Based on values of literature. *Joint level of effort = 1.*
5.	Carbon stock	**Carbon sequestered in annual crops** *Rationale:* Influences the carbon flows related to land use change. The impact should be lower than for perennials, which makes it lower priority. *Feasibility/requirements:* Some standard values can be applied to most important crops proportionally to the length of their cultivation cycle.	Medium	1	Advises to implement.
6.	Carbon stock	**Differentiating use of wood from carbon emissions from deforestation** *Rationale:* Influences the emission factors of deforestation. However, according to EPA RIA, the difference stays small after a couple of decades. Because a sensitivity analysis on emission factors is already planned, this improvement may not have high priority. *Feasibility/requirements:* would require significant data and work on the use of different products from forest degradation and clearing as well as their life cycle emissions in different regions of the world.	Medium	5	Not discussed.
7.	Carbon stock	**Peatland emissions factors** *Rationale:* Peatland emission factors are frequently discussed in the ILUC debate and can significantly affect results on emissions in Indonesia/Malaysia. *Feasibility/requirements:* Different articles provide different estimates. Extensive and critical literature review required and sensitivity analysis	High	1	Advises to go for a simpler solution. Overview of literature value and apply in MC.
8.	Carbon stock	**Expand inclusion of soil organic carbon (SOC) to rest of the world** *Rationale:* Influences emission factors of agricultural land expansion. *Feasibility/requirements:* SOC in agricultural land is closely related to tillage practices. Therefore, such an improvement would require: - expansion of SOC data in the model using a global dataset to be identified	High	5, simpler solution: 1	Advises to go for a simpler solution.

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		- describing tillage practices in the different supply units of the model (data availability issue) *The level of effort would be reduced to 1 if data on SOC are introduced without tillage representation in the rest of the world. Average tillage assumption will tentatively be used at regional level when data is accessible (e.g. US, Brazil or Argentina).*			
9.	Carbon stock	**Forest regrowth and reversion time** *Rationale:* Influences carbon stock in unmanaged land and changes opportunity costs of using abandoned land. *Feasibility/requirements:* requires a geographically explicit assessment of carbon stock associated to primary vegetation and length of reversion time.	High	3 simpler solution: 1	Advises to go for a simpler solution, possibly using IPCC default values. To add to MC analysis. *Level of effort =1.*
10.	Carbon stock	**Introduce forest degradation** *Rationale:* Degradation is a source of additional emissions and also a source of additional deforestation. It is however less connected to agricultural development than deforestation. *Feasibility/requirements:* Modelling forest degradation is a complex challenge. It requires: - representation of the 'initial' level of forest degradation (knowledge gaps) - modelling of drivers of forest degradation - modelling of links between degradation and deforestation	Medium	10	Not discussed.
11.	Co-product	**Improve protein and energy content representation to refine co-product substitution** *Rationale:* Co-product substitution is currently represented in the model, accounting for both protein and energy content. Substitution patterns are a highly debated topic, therefore, fine tuning of this mechanism seems important to produce reliable substitution effects. *Feasibility/requirements:* The refinement would consist of: - Testing substitution in different livestock sectors and comparing substitution patterns with literature - Implementing incorporation constraints for each sector	High	2	Advises to implement. Important to invest time necessary to clarify and improve mechanisms.
12.	Co-products	**Introduce additional constraints on co-products related to contents of amino-**	Medium	2	Discussed but advises not

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		acids, fibers, etc. *Rationale:* content of other nutrients is relevant to refine further substitution behavior of co-products. *Feasibility/requirements:* requires addition of data on the nutrient contents of feed and comparison of the new substitution effects with the previously observed ones.			to treat as highest priority.
13.	Co-products	**Distinguish dry DDGS and wet WDG** *Rationale:* content of different types of co-products have different nutrition characteristics and substitute differently. *Feasibility/requirements:* requires data on production and use of the different co-product types in Europe.	Medium	2	Discussed but advises not to treat as highest priority.
14.	Co-products	**Introduce yield effect from increased digestibility for animals fed with co-products** *Rationale:* increased digestibility of feed with co-product consumption would increase animal productivity and change the overall feed need and therefore the co-product substitution ratio. *Feasibility/requirements:* a consistent assessment of this effect would require running the digestibility model used to obtain the input dataset used in GLOBIOM. This can hardly be envisaged in the context of this project	Medium	10.	Not discussed.
15.	Crop management	**Include effect of Multi-cropping** *Rationale:* multi-cropping increases production per ha and reduces agricultural land expansion. It can therefore influence the land use change response. *Feasibility/requirements:* representing multi-cropping responses requires: - data on current multi-cropping practices in a geographically explicit setting - running the crop model with multi-crop systems for the different regions with multi-cropping - representing in the model the behaviors of farmers with respect to multi-cropping	High	10 simpler solution: 1	Advises to go for a simpler solution. Too challenging to model multi-cropping response to price. Advise to consider this effect at least for the baseline, with yield projections.
16.	Crop management	**Distinguish the different intensification effects from N, P and K** *Rationale:* Intensification of N fertilizer increases GHG emissions. But intensification can also occur through addition of P or K, with lower impacts on	Low	10	Discussed but advises not to treat as highest priority.

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		GHG emissions. Considering the project will focus mainly on land use change emissions, refinements of crop emissions are of lower priority. *Feasibility/requirements:* modelling different effects of N, P and K would require: - running the EPIC model along the P and K intensification gradients in addition to the N one - modelling separately N, P and K demand in GLOBIOM to represent how farmers determine the final mix of products			
17.	Crop management	**Add perennial Arundo Donax** *Rationale:* Arundo Donax is one of the crops that could be used on marginal land to produce second generation biofuels. *Feasibility/requirements:* Arundo Donax is not present in the EPIC model. Therefore, it cannot be used in the EPIC rotations and modelled in GLOBIOM. *An alternative to modelling Arundo Donax would be to replace it by a similar crop from an agronomic perspective.*	Medium	not feasible	Not discussed.
18.	Crop management	**Yield response to price through investment instead of management change** *Rationale:* investment would allow for additional yield increase to management intensification. This effect can play on role in long term but sensitivity analysis will allow for assessing a large range of sensitivity to yield response. *Feasibility/requirements:* modelling the link between prices and long term productivity is a significant research challenge. Capital and research and development are not represented in GLOBIOM, which makes it even more difficult to implement this suggested improvement.	Medium	10	Discussed but advises not to treat as highest priority.
19.	Crop management	**Represent supply constraints on fertilizer markets** *Rationale:* Yield response can be limited if some rigidity appears on the fertilizer market because the input price would increase. This effect can in particular play a role in short-term analyses, but may be of lower priority for the long run. *Feasibility/requirements:* introducing a domestic fertilizer market in the model would be feasible if supply elasticities of fertilizer in the different regions are	Low	2	Not discussed.

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		known.			
20.	Crop management	**Improve fertiliser emission data using updated data** *Rationale:* GHG emission per crop can be updated using more recent estimates from the International Fertilizer Association. Considering the assessment will focus first on land use change emission, this improvement has lower priority. *Feasibility/requirements:* In the case where updated data could be obtained, this improvement could be done without difficulty.	Low	1	Discussed but advises not to treat as highest priority.
21.	Demand	**Imperfect substitution of vegetable oils** *Rationale:* currently GLOBIOM can only represent perfect substitution or complementarity of vegetable oils. Market leakage across vegetable oil markets is key to the impact of biodiesel but is ruled by some imperfect substitution that would be important to introduce in GLOBIOM. *Feasibility/requirements:* Representing imperfect substitution in GLOBIOM requires: - information about substitution possibilities of different types of vegetable oils - estimates of elasticities of substitution - introduction of some non-linear cost of substitution on the demand side of the model *Simpler solution: effort can be reduced to 2 units if substitution elasticities are based on previous modelling exercises*	High	3 simpler solution 2	Advises to implement. Very important to track this effect.
22.	Demand	**Cross-price elasticities on cereals or others group of products** *Rationale:* As for vegetable oils, some other products can imperfectly substitute on the final demand side. For instance, cereals are have also similarities for the final consumer, which gives some degree of substitution, although this effect is already dealt with in the livestock sector, which puts it at lower priority level then vegetable oils. *Feasibility/requirements:* If representation of imperfect substitution for vegetable oils is working, expanding the approach to some other products only requires: - information about substitution possibilities of different substitutable products - estimates of elasticities of substitution	Medium	1	Advises to implement.
23.	Energy	**Introduce a simplified fuel market**	Low	5	Not discussed.

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		Rationale: besides the ILUC effect, literature is pointing out the leakage of GHG emissions through the fuel market. Considering that this study will focus on ILUC effect, assessing the extent of this leakage appears to be of lower priority. *Feasibility/requirements:* introducing realistic representation of the fuel market in GLOBIOM would technically be feasible but would require: - collection of market data on supply and demand of oil and main refined products - information on supply and demand elasticities in different regions - information of tax levels associated to the fuel market *A more stylized representation with only an integrated fuel world market and a unique supply and demand elasticity at world level would allow to reduce the level of effort to 2.*			
24.	Region resolution	**Separate representation of Argentina, Indonesia and Malaysia** *Rationale:* Argentina, Indonesia and Malaysia are important players on the biofuel market, but also for land use change dynamics. *Feasibility/requirements:* disaggregation of regions in GLOBIOM is not a problem from a data perspective. It requires however some testing to check impact on model behavior.	High	2	No clear advice on whether to implement or not. Implementing the separate representation would improve economic-geographical allocation of mainly palm oil, but not seen as highest priority compared to other points.
25.	Region resolution	**Separate representation of Ukraine** *Rationale:* Ukraine is not an important player on the biofuel market today and is from this perspective of lower priority than Argentina, Indonesia and Malaysia. But it could play an important role in the future as a supplier of agricultural products to the EU market. *Feasibility/requirements:* disaggregation of regions in GLOBIOM is not a problem from a data perspective. It requires however some testing to check impact on model behavior.	Medium	1 less if combine with 24	Advises not to implement. May be interesting for some policy analysis but not a high priority from an ILUC modelling perspective.

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26.	Infrastructure	**Representation of intra-region transportation costs in the EU** *Rationale:* Transportation costs shape the geographic allocation of feedstock production within countries and determines more precisely land use change patterns. It is therefore considered of high priority. *Feasibility/requirements:* representing transportation costs in the EU would require substantial efforts to: - identifying a method of costing adapted to model resolution level currently used - calculating transportation costs through GIS approach and implementing them in the model for the different products - calibrating the production with the new transportation costs - testing the model behavior and consistency	High	7	Advises no to implement. Too challenging issue.
27.	Land available	**Represent unused agricultural land in Europe** *Rationale:* some large amounts of abandoned or marginal land exist in continental Europe that could be potentially be used to produce additional quantities of feedstocks. Using this land would limit expansion in other regions of the world. *Feasibility/requirements:* representing more explicitly unused land is possible in GLOBIOM if: - data on unused agricultural land can be gathered - an "unused" land type is created in GLOBIOM - a consistent calibration is performed that consistently describes the dynamics of this land type	High	3	Advises to implement. *AC advices to implement in main scenario. However, a simpler solution could be implemented by modeling scenario C (see Proposal for Baseline and Scenarios document) without explicit land characterization, only by varying expansion costs in other natural land in the EU.* *This would transfer the effort to the modeling effort of the project.*
28.	Land available	**Improve data on degraded cropland and pasture, and associated SOC carbon stock** *Rationale*: Some soil organic carbon is already depleted in land where agriculture can expand. This also applies to cropland that is not covered by any of the FAO crops but cultivated for other purposes. Therefore, taking degradation into	Medium	10	Not discussed.

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		account is important to avoid an overestimation of SOC carbon emitted due to expansion of harvested crops. *Feasibility/requirements:* this improvement would require introducing SOC data in the regions concerned by these improvements (already present in EU). But also data on degraded land and the associated soil carbon depletion. This latter point seems particularly challenging considering the current data situation and would imply very large research efforts that go beyond the scope of this project.			
29.	Land use change	**Expansion of plantations into peatland** *Rationale:* Demand for palm oil and other drivers have led to significant deforestation and peatland drainage in South-East Asia and associated carbon emissions. It is therefore important to understand the dynamics of expansion to assess possible future emissions associated to this expansion. *Feasibility/requirements:* representing explicitly the dynamics of plantation expansion in South-East Asia implies several challenges: - disaggregating the geographical resolution of South-East Asia to 50 x 50 km - obtaining and introducing peatland maps in the model - introducing maps of plantation locations in the model - testing and performing consistency checks on plantation expansion dynamics in the model Because an explicit representation of expansion on peatland would represent substantial efforts and a suitability criterion could be challenged by historical development, a quicker approach could be to analyse historical data. An analysis based on a literature review, assessing historical share of plantation expansion into peatland, would reduce the level of effort to 1.	High	6 simpler solution: 1	Advises not to implement. Expansion on peatland on a suitability basis is too challenging. AC Advises to go for a simpler solution*: rely a on a literature review of expansion of palm plantations into peatland.*
30.	Land use change	**Additional drivers of deforestation** *Rationale:* GLOBIOM currently only represents agricultural drivers of deforestation. But other deforestation mechanisms are at play, in particular mining, infrastructure, urbanization. Degradation through fuel wood collection, illegal logging, etc. can also exacerbate deforestation. Because biofuels mainly influence agricultural drivers, and these are estimated to represent 80% of total deforestation, this improvement does not appear as high priority as some others.	Medium	10	Discussed but advises not to treat as highest priority.

Nr	Topic	Improvement	Priority	Effort units	Advice from AC
		Feasibility/requirements: missing drivers are mining, infrastructure and urbanization. Introducing these drivers in the baseline would imply a large work of collection of datasets on future developments of these drivers and how they influence deforestation in the model. Forest degradation is discussed in a different improvement.			
31.	Land use change	**Improve land cover/use datasets** *Rationale:* In spite of remote sensing capacities, land cover and land use datasets still contain imperfections and require improvement. The efforts in that direction are important to improve modelling of land use change. *Feasibility/requirements:* GLOBIOM already makes use of the best statistical products available on land cover and land use, and IIASA is participating in research community efforts to improve the quality of this information. The level of effort needed to progress substantially on this question however goes well beyond the scope of this project. This improvement is therefore not feasible now.	High	Not feas.	Advises not to implement. Too challenging research topic that goes beyond the scope of this project.
32.	Livestock	**Improve representation of livestock intensification (Brazil)** *Rationale:* Intensification of livestock in Brazil has limited agricultural expansion significantly and continues to influence land use dynamics in that region. Representation of this intensification is therefore important to avoid overestimating land use impacts from agricultural production in Brazil. *Feasibility/requirements:* GLOBIOM has already a mechanism to represent livestock intensification in the model (through shifts in management systems and reallocation). Fine-tuning the intensification process would require substantial efforts to: - improve livestock structure data for Brazil at at subnational level - improve pasture and grazing information quality - obtain information on livestock intensification elasticities	Medium	5	Discussed but advises not to treat as highest priority. AC advises to present results with more intuitive indicators than just the one (feed consumption rate) currently used in GLOBIOM.
33.	Livestock	**Improve GHG emissions using USDA PSD information** *Rationale:* current livestock emissions in GLOBIOM are based on feed consumption and livestock production data but do not take into account information on ruminant herd structure such as available from USDA for some countries. Using that information could allow for fine-tuning livestock emission	Low	10	Discussed but advises not to treat as highest priority.

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		estimates. Considering that livestock emissions are not the direct focus of this project, this improvement is considered of lower priority than those related to land use change emissions. *Feasibility/requirements:* A significant effort of two years has been achieved recently to refine livestock data currently used in GLOBIOM, using a digestibility model. Going a step further in the data production would require an important effort to refine the complex methodology used.			
34.	Technologies	**Refine oilseed crushing coefficients** *Rationale:* crushing rates are important to determine the final land use impact of oilseed products. Coefficients used in GLOBIOM should be fine-tuned. *Feasibility/requirements:* if data are provided to the team, the crushing ratios in the model can be updated, and market balance data from FAO adapted accordingly. Information for other regions than Europe would also be highly desirable to avoid introducing a bias towards EU productivity.	High	1	Advises to implement.
35.	Technologies	**Conventional and advanced biofuel production conversion coefficients to refine** *Rationale:* conversion efficiency is important to determine the final land use impact of biofuel feedstock use. Coefficients used in GLOBIOM should be fine-tuned. *Feasibility/requirements:* if data are provided to the team, the conversion efficiencies can be updated. Information for other regions than Europe would also be highly desirable to avoid introducing a bias towards EU productivity.	High	1	Advises to implement.
36.	Technologies	**Add relevant input/co-products in most recent technologies for both 1st and 2nd gen** *Rationale:* some biofuel pathways can require specific inputs or produce outputs (e.g. corn oil) that influence the total land use requirements. Properly representing these products therefore can affect ILUC. *Feasibility/requirements:* if data are provided to the team, the model supply chains can be updated. New products of relevance can be added if market information (supply, use, trade) is available. Final level of effort depends on number of products to add (level 1 for no more than one product).	High	1	Advises to implement on the understanding that it doesn't substantially reduce capacity to undertake other tasks, reduced effort possible?

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37.	Time	**Reduce time-step to 5 years** *Rationale:* the model currently runs with ten year time-steps and moving to five years would allow a more precise baseline. However, because results for 2020 and 2030 should be analysed, it is not clear what the added value of such a change would be. *Feasibility/requirements:* changing the time step would require to recalibrate the model for this adjustment. The change would double the time needed to run the model, which would limit the number of sensitivity analyses that can be performed at a later stage in the project.	Low	3	Not discussed.