Description of the GLOBIOM model

17 September 2013, Ecofys, IIASA, E4tech

Ecofys, IIASA and E4tech are jointly undertaking a project for the European Commission (DG ENERGY) on the modelling of ILUC associated with conventional and advanced biofuels consumed in the EU. The GLOBIOM[1] partial equilibrium model, developed by IIASA, will be used for this purpose. Results are expected in 2015. A brief description of the GLOBIOM model is provided below. Stakeholders are invited to submit comments and suggestions on the modelling of ILUC using the GLOBIOM model via ILUC@ecofys.com

What is GLOBIOM?
GLOBIOM (Global Biosphere Management Model) is a global recursive dynamic partial equilibrium model with a bottom-up representation of agricultural, forestry and bioenergy sectors. The model is global because it covers 53 countries and regions worldwide (EU28 plus 23 countries and regions in rest of world). GLOBIOM is recursive dynamic instead of static, and is thus able to model changes over periods of time. The model is partial equilibrium as opposed to general equilibrium because it covers the most relevant sectors (agriculture and forestry) in great detail while other sectors are included in a less detailed way. And GLOBIOM is bottom up rather than top-down because the supply side of the model is built-up from bottom (land cover, land use, management systems) to top (production/markets).

The model computes the global agricultural and forest market equilibrium by choosing land use and processing activities to maximise the sum of producer and consumer surplus, subject to resource, technological and policy constraints. The level of production in a given area is determined by the agricultural or forestry profitability in that area (dependant on suitability and management), by market prices (reflecting the level of demand), and by the conditions and cost associating to conversion of the land, to expansion of the production and, when relevant, to international market access. Trade is modelled following the spatial equilibrium approach, which means that the trade flows are balanced out between different specific geographical regions. This allows tracing of bilateral trade flows between individual regions.

By including not only the bioenergy sector but also forestry, cropland and grassland management, and livestock management, the model allows for a full account of all agriculture and forestry GHG sources. GLOBIOM accounts for ten sources of GHG emissions, including crop cultivation N_2O emissions from fertilizer use, CH_4 from rice cultivation, livestock CH_4 emissions, CH_4 and N_2O emissions from manure management, N_2O from manure applied on pasture, above and below ground biomass CO_2 emissions from biomass removal after converting forest and natural land to cropland, CO_2 emissions from soil carbon included cultivated organic soil (drained peatland, at country level). These emissions inventories are based on IPCC accounting guidelines.

---

[1] See also www.globiom.org

<div style="border:1px solid">

GLOBIOM features in brief:

1. Consistency in quantity and prices reporting: all information in GLOBIOM is sourced from FAOSTAT and EUROSTAT.

2. Explicit representation of land in the model. In GLOBIOM, all land cover types are at any time explicitly represented in the model with all their biophysical characteristics, which ensures a high level of transparency and robustness.

3. Simultaneous representation of agriculture and forestry sector with sufficient detail. GLOBIOM uses information on yield, harvesting costs and carbon stocks at the level of gridcells of 10x10 km to 50x50km, using biophysical models. For crops, different management systems are available, which ensures the technological consistency of endogenous yield responses.

4. Representation of feed product substitution The GLOBIOM structure allows the application of several complementary constraints to represent the different feed requirements of animals in terms of both energy and protein simultaneously.

5. Grassland representation: GLOBIOM relies on precise maps on land cover, animal location and Net primary productivity to infer the quantities of grass consumed by animals and the pressure on land from the livestock system.

</div>

GLOBIOM uses detailed and reliable statistics and maps

All processes and management options are represented at a high level of regional detail and built on trustworthy databases. GLOBIOM and G4M are based on EU data regarding area, yields, production etc. at NUTS 2 level. The market balances calculated for the 53 regions relies on EUROSTAT accounts and on FAOSTAT for outside EU. Land cover is dealt with in a geographically explicit way. The land cover description for the EU28 is based on CORINE/PELCOM cover maps, which ensure a great level of detail in land cover. The land cover for the rest of the World is based on GLC 2000. Land cover can change in GLOBIOM under the effect of agriculture and forestry development. Six land use categories dynamically interact: cropland, grassland, managed forest, primary forest, other natural land and short rotation plantations. Possibilities and cost of conversion from each land use type to another can be specified independently through land transition matrixes. Conservation areas and biodiversity hotspots can be easily identified in this framework in order to test the sensitivity of the modelling outputs to the inclusion of sustainability criteria constraints on biofuels.

Categories of biomass and biomass conversion are included in GLOBIOM

GLOBIOM represents a number of conventional and advanced biofuels feedstocks:

- 27 different crops including 4 vegetable oil types[2];
- Co-products: 3 oilseed meal types, wheat and corn DDGS;
- Perennials and short rotation plantations: Miscanthus, switchgrass, short rotation coppice;
- Managed forest: stem wood, primary forestry residues, secondary forestry residues from forest industries and milling activities, tertiary forestry residues (recovered wood products);
- Crop residues (e.g. straw).

---

[2] Palm oil, rapeseed oil, soy oil and sunflower oil

Various energy **conversion processes** are modelled in GLOBIOM and implemented with specific technological costs, conversion efficiencies and co-products:

- Wood (forestry): sawn wood, pulp and paper production, combustion, fermentation, gasification;
- Lignocellulose (energy crop plantations): combustion, fermentation, gasification;
- Conventional ethanol: corn, sugar cane, sugar beet and wheat ethanol processing;
- Conventional biodiesel: rapeseed oil, soybean oil, soya oil and palm oil to FAME processing;
- Oilseed crushing activities: rapeseed, soybeans, and sunflower crushing activities.

This allows ethanol, methanol, biodiesel, heat, electricity and gas to be distinguished and traced according to their feedstock

How are biofuel co-products treated in GLOBIOM?

All main co-products of biofuel production (cakes and DDGS) are explicitly represented in the model. Co-products of biofuels have an impact on total GHG emissions of biofuel production if they can substitute other products, such as feed. In GLOBIOM, the insertion of co-products into the feed ratio is handled for each of the eight animal types in the model with a full set of feed nutrition optimisation equations. In GLOBIOM, animals rations are calculated by taking into account both energy and protein requirements. This allows for a sophisticated representation of animal feed substitution by co-products.

How are agricultural yield and yield trends included in GLOBIOM?

GLOBIOM has an endogenous[3] yield response to producer prices. There are three different mechanisms that rule endogenous yield response to a price increase: 1) Yields can increase due to an intensification caused by shifts between rainfed management types (subsistence, low input and high input), rotation and three tilling practices; 2) In addition yields change when irrigated systems are developed. This development is represented in GLOBIOM based on a regional water supply curve and two levels of intensification in irrigated systems; 3) Finally, crop reallocation occurs during the optimisation across simulation units with different properties (climate and soil conditions) causing changes in yield levels. An exogenous[3] yield component also represents the effects on yields not covered by the three points above (e.g. breeding and technological progress).

GLOBIOM draws on results from the crop model EPIC (Environmental Policy Integrated Climate Model), which provides the detailed biophysical[4] processes of water, carbon and nitrogen cycling, as well as erosion and impacts of management practices on these cycles. GLOBIOM therefore incorporates all inputs that affect yield heterogeneity and can also represent a different marginal yield for different crops in a same grid cell. EPIC simulations with detailed representation of management systems and crop rotations have been incorporated into GLOBIOM for the EU28 at NUTS2 level.

GLOBIOM benefits from a detailed supply side but also incorporates a full representation of final consumption based on the most up to date price demand elasticities estimated at USDA[5]. Final demand is consistent with the FAO Food Balance Sheet structure.

---

[3] Endogenous means that a certain fixed parameter included in the model. The opposite is 'exogenous' which indicates dynamic, external parameters which are added to the model, for example GDP growth rates.

[4] Biophysical means related to living (animals, plants) and non-living (light, temperature, water, soil etc.) factors in the environment which affect ecosystems

[5] United States department of Agriculture

Detailed modelling of forestry biomass through G4M model

The response of forests in the EU and abroad to increased demand for biomass is expected to be complex and dynamic due to the effects of age classes, species composition and regrowth after harvest. Impacts on forests are therefore assessed with a separate forestry model. G4M uses information on age class distribution and species distribution of European forests and is geographically explicit at half degree resolution. G4M can model change in forest biomass supply through alternative forest management, deforestation and afforestation.
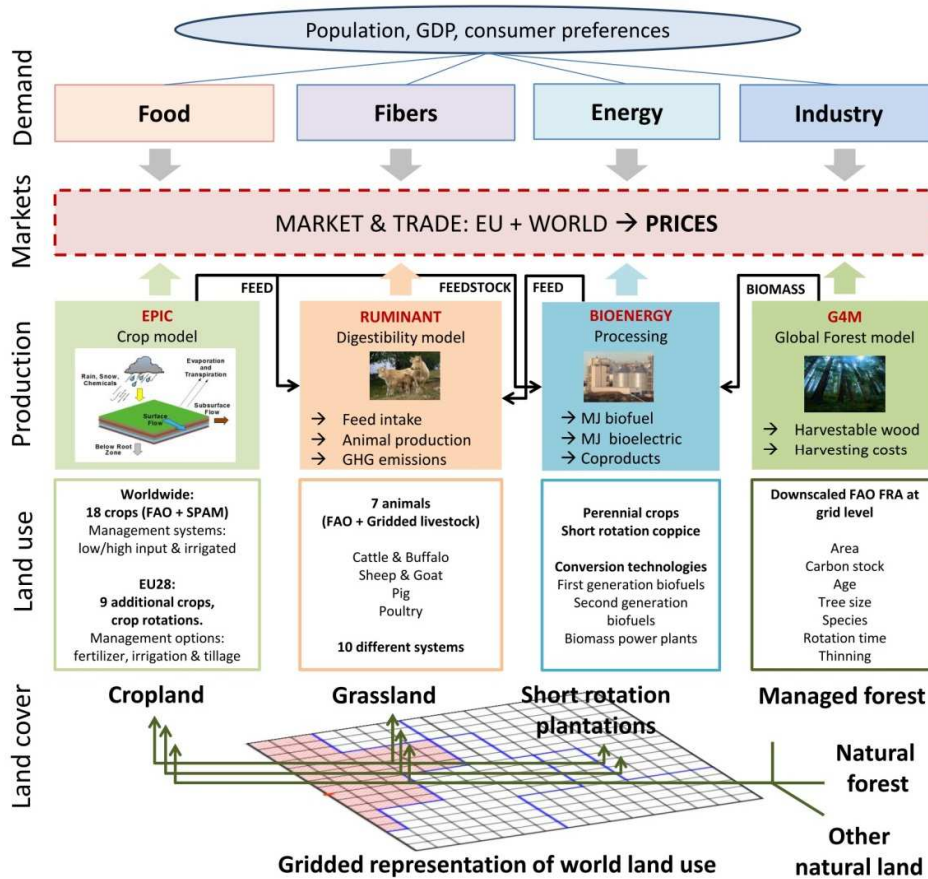

Illustration of the GLOBIOM model

Further reading

Havlík, P., Schneider, U. A., Schmid, E., Böttcher, H., Fritz, S., Skalský, R., Aoki, K., Cara, S. D., Kindermann, G., Kraxner, F., Leduc, S., McCallum, I., Mosnier, A., Sauer, T. & Obersteiner, M. (2011). Global land-use implications of first and second generation biofuel targets. Energy Policy 39 (10), 5690 - 5702. http://www.sciencedirect.com/science/article/pii/S030142151000193X **[Restricted access]**

Mosnier, A., Havlík, P., Valin, H., Baker, J., Murray, B., Feng, S., Obersteiner, M., McCarl, B., Rose, S. & Schneider, U. (2013). Alternative U.S. biofuel mandates and global emissions: The role of land use change, crop management and yield growth. [Report version available at http://nicholasinstitute.duke.edu/climate/policydesign/net-global-effects-of-alternative-u.s.-biofuel-mandates **[Open access]**

Frank, S., Böttcher, H., Havlík, P., Valin, H., Mosnier, A., Obersteiner, M., Schmid, E. & Elbersen, B. (2012). How effective are the sustainability criteria accompanying the European Union 2020 biofuel targets?. GCB Bioenergy, http://onlinelibrary.wiley.com/doi/10.1111/j.1757-1707.2012.01188.x/abstract;jsessionid=FE518E1B459CAEBBF3BA05B51409CF77.d02t04 **[Restricted access]**

Valin, H., Havlík, P., Mosnier, A., Herrero, M., Schmid, E. & Obersteiner, M. (2013). Agricultural productivity and greenhouse gas emissions: trade-offs or synergies between mitigation and food security?. Environmental Research Letters 8 (3), 035019. http://iopscience.iop.org/1748-9326/8/3/035019/ **[Open Access]**