

Biomass role in achieving the Climate Change & Renewables EU policy targets. Demand and Supply dynamics under the perspective of stakeholders . IEE 08 653 SI2. 529 241

Modelling biomass supply options with GLOBIOM: A non-technical introduction (Policy briefing under D6.4)

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Preface

This publication is part of the BIOMASS FUTURES project (Biomass role in achieving the Climate Change & Renewables EU policy targets. Demand and Supply dynamics under the perspective of stakeholders - IEE 08 653 SI2. 529 241, www.biomassfutures.eu) funded by the European Union's Intelligent Energy Programme.

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1 Introduction

The Global Biosphere Management Model (GLOBIOM)¹ has been developed and is used at the International Institute for Applied Systems Analysis (IIASA)². In the context of Biomass Futures IIASA is applying the model in work package 3 in relation to biomass availability and supply analysis. GLOBIOM is used to determine the competitive economic potential for different biomass sources and determine the supply patterns for energy crops and forest biomass based on spatial availability analysis for cropped biomass conducted by Alterra³.

The purpose of this policy briefing is to provide a non-technical introduction to the GLOBIOM model enabling policy makers and other stakeholders to understand the results generated with GLOBIOM in the Biomass Futures context and to get an understanding about the main drivers of results. A forthcoming policy briefing will follow up on this and go beyond GLOBIOM by explaining the comprehensive modelling framework of the Biomass Futures project.

2 The basic GLOBIOM model

GLOBIOM is a global recursive dynamic partial equilibrium model integrating the agricultural, bioenergy and forestry sectors with the aim to provide policy analysis on global issues concerning land use competition between the major land-based production sectors. It is *global* in the sense that it encompasses all world regions aggregated in a way that can be altered. For the purpose of Biomass Futures, GLOBIOM covers 50 regions.⁴ *Partial* denotes that the model does not include the whole range of economic sectors in a country or region but specialises on agricultural and forestry production as well as bioenergy production. These sectors are, however, modelled in a detailed way accounting for about 20 globally most important crops, a range of livestock production activities, forestry commodities as well as different energy transformation pathways.

GLOBIOM disaggregates available land into several land cover/use classes that deliver raw materials for wood processing, bioenergy processing and livestock feeding. Figure 1 illustrates this structure of different land uses and commodities. Forest land is made up of two categories (unmanaged forest and managed forest); the other categories include cropland, short rotation tree plantations, grassland (managed grassland) and 'other natural vegetation' (includes unused grassland).

The detailed modelling of land based activities means that the GLOBIOM model relies on a detailed database containing geo-spatial information. This information is made up of different layers: geo-spatial characteristics that do not change over time (due to climate change and/or management practices) such as altitude, slope, and soil are used to form geographical clusters or 'Homogenous Response Units' (HRU). On top of this layer containing time invariant characteristics come country boundaries and a 0.5° x 0.5° grid layer that contains more detailed information such as data on climate, land use/cover, etc. This information forms Simulation Units (SimU) that are the basic geographical unit for the analysis. For

¹ Documentation of the GLOBIOM model can be found at www.globiom.org. The information in this briefing is mainly taken personal communication with Hannes Boettcher and Stefan Frank at IIASA, from Havlík *et al* (in press) and Schneider *et al* (2011) as well as from the Biomass Futures deliverable D3.4, available at http://www.biomassfutures.eu/work_packages/work_packages.html.

² <http://www.iiasa.ac.at/>

³ <http://www.terra.wur.nl/uk/>

⁴ The 50 regions are a disaggregated representation of an eleven-region GLOBIOM version adapted to enable linkage with the POLES and/or PRIMES model. The disaggregation of the EU into 27 individual countries has been performed recently for the Biomass Futures project, originally five European region are defined (<http://www.iiasa.ac.at/Research/FOR/globiom/regions.html>).

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each SimU, different management systems are distinguished. For the bulk of global crop production four management systems are available in GLOBIOM; these are irrigated, high input – rainfed, low input – rainfed and subsistence management.

The global agricultural and forest market equilibrium is computed by choosing land use and processing activities to maximize welfare (ie the sum of producer and consumer surplus) subject to resource, technological, and policy constraints. These constraints ensure that demand and supply for *inter alia* irrigation water and land meet but also impose exogenous demand constraints so as to reach, for instance, a certain biofuel target. Prices and international trade flows are endogenously determined for respective aggregated world regions (ie in this context for the 50 regions mentioned above). Imported and domestic goods are assumed to be identical (homogenous), but the modelling of trade does take into account transportation costs and tariffs. GLOBIOM includes accounting for greenhouse gas emissions and sinks from agricultural and forestry activities. This includes among others accounting for N₂O emissions from fertiliser use whose intensity in turn depends on the management system.⁵

It is possible within the model to convert one land cover/use to another; the total land area spanning all the categories included remains fixed, however (this forms part of the constraints mentioned earlier). The arrows on the left-hand side of Figure 1 indicate the initial land category and therefore show the way in which land cover/use can change (ie unmanaged forest can be converted into managed forest or cropland). The greenhouse gas consequences from land use change are derived from the carbon content of above- and below-ground living biomass of the respective land cover classes.

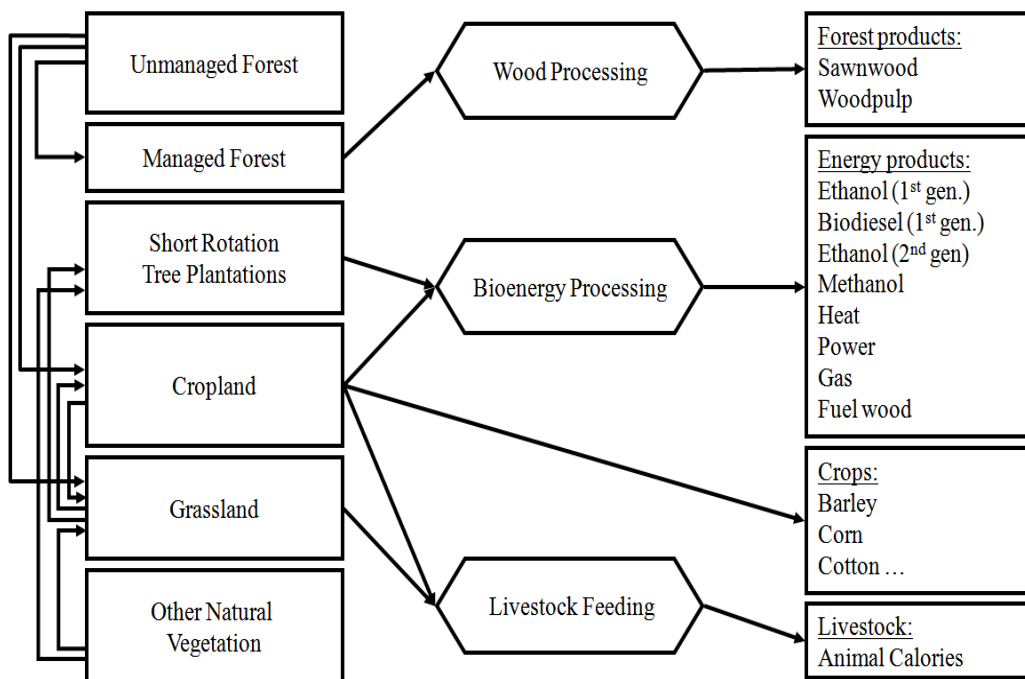


Figure 1. GLOBIOM land use and product structures (Havlík *et al*, in press). Note: The arrows on the left represent the direction where a given land use/cover type can expand given the current constraints in the model.

The model is *recursive dynamic* in the sense that changes in land use made in one period alter the land availability in the different categories in the next period. Land use change is thus transmitted from one

⁵ The calculation of N₂O emissions is in accordance with IPCC 1996, which does not take detailed soil characteristics into account (such as soil carbon content) that can have important implications for the amount of emissions.

period to the next. As GLOBIOM is a partial equilibrium model, not all economic sectors are modelled explicitly. Instead, several parameters enter the model exogenously, or are pre-determined in other words, including wood and food demand which in turn are derived from changes over time in gross domestic product (GDP), population (same projections as used in PRIMES) and food (calorie) consumption per capita (projections according to FAO 2006). Assumptions on GDP, population growth and calorie consumption per capita are the underlying driver of the model dynamics. The base year for the model is the year 2000, the model horizon in Biomass Futures is 2030. The exogenous drivers population and GDP growth have been updated to take recent economic downturns into account by relying on 2009 data. In relation to yield development, GLOBIOM typically assumes 0.5 % autonomous technological progress in crop improvement⁶; in addition, the possibility to shift between management systems as well as the relocation of crops to more productive areas also provides for regional average yield changes. When it comes to 'bioenergy dynamics', projections from the POLES model⁷ (for regions outside Europe) and the PRIMES model (for EU 27 countries) on regional biomass demand in heat and power (BIOINEL), direct biomass use ie for cooking (BIOINBIOD) and liquid transport fuel use (BFP1 and BFP2 or first and second generation biofuels, respectively) over the next two decades are implemented in GLOBIOM as target demands or minimum demand constraints.

Resources for the different types of bioenergy products can be sourced from agricultural and (existing) forestry activities but also from newly planted short rotation tree plantations. First generation biofuels include ethanol made from sugarcane, corn and wheat, and biodiesel made from rapeseed, palm oil and soybeans. Biomass for second generation biofuels is either sourced from existing forests/wood processing or from short rotation tree plantations. Havlík *et al* (in press) define different scenarios for the sourcing of second generation biofuels. They also conducted an analysis to establish the scale of land available for short rotation tree plantations. Summarised in a few words, they arrive at available area by excluding areas unsuitable for their level of aridity, temperatures, elevation and population density from total arable land area (grassland, cropland, 'other natural vegetation').

Recent applications of GLOBIOM have analysed the impacts of different development scenarios in terms of population growth, economic development and technical change on global food production and consumption (Schneider *et al*, 2011) as well as the global land-use implications of first and second generation biofuel targets (Havlík *et al*, in press). The explicit inclusion of water as a resource (along with land and irrigated land) makes GLOBIOM a strong tool for analysing water related impacts of different development scenarios (Sauer *et al*, 2010).

3 Modifications for Biomass Futures

The Biomass Futures project defines sustainability criteria and analyses their impact on biomass availability. The National Renewable Energy Action Plans (NREAPs) contain information about how the Member States expect to meet their 2020 targets, including the technology mix and the trajectory. This information enters GLOBIOM and the model is then solved taking into account the different constraints on biomass imports, production and demand for first and second generation biofuels, electricity and heat in 2020. An additional scenario analysis compares the results of these 'NREAP scenarios' with PRIMES (bioenergy demand for EU 27 according to the PRIMES model) and POLES (global bioenergy demand according to POLES model) scenario results. A precondition for the NREAP modelling was to refine the regional disaggregation of GLOBIOM to include all 27 Member States as single-country regions.

⁶ Note that Havlík *et al* (in press) work with a different, ie zero per cent, yield assumption.

⁷ Taken from the 2010 POLES (Prospective Outlook on Long-Term Energy Systems) baseline scenario. See <http://www.enerdata.net/enerdatauk/solutions/energy-models/poles-model.php> for POLES documentation.

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In terms of sustainability constraints, it is currently assumed that 5 per cent of cropland and 'other natural vegetation' can be converted to short rotation tree plantations per period (ie 10 years). A forthcoming Biomass Futures Briefing will discuss further sustainability constraints potentially implemented in the course of the Biomass Futures project⁸.

4 Main drivers and crucial parameters

The main drivers of results and crucial underlying assumptions are the following:

- Yield assumption: 0.5 % autonomous yield increase per year due to technical progress typically assumed.⁹ This assumption can be easily altered in GLOBIOM to reflect latest available yield projections or to run sensitivity scenarios;
- Calorie consumption per capita derived from projections according to FAO (2006);
- Bio energy supply is derived from PRIMES modelling results;
- Available land reserve and availability to convert grassland and 'other natural vegetation': 5 per cent of area per period (10-year periods) allowed to be converted to short rotation plantings.

Research in other work packages of the Biomass Futures project will allow GLOBIOM to be updated based on most recent information on the latter two bullet points. Alterra analyses the spatial availability of different biomass supply options and Oeko-Institut¹⁰ defines together with Alterra sustainability criteria and analyses in how far their implementation impacts on biomass supply.

References

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⁸ Recently biodiversity constraints have been implemented in GLOBIOM so as to exclude highly biodiverse areas from the available land reserve for new plantations.

⁹ Note that autonomous yield increase is only one of three components of the yield change in GLOBIOM. The other two components are management system change (intensification) and shift of the production to more or less yielding zones (re-allocation). It was found that the 0.5 value enables best to reproduce recent total yield changes according to FAOSTAT. Disaggregated data which would enable to define the autonomous yield growth in a less arbitrary and more differentiated way (by region and crop) is not available.

¹⁰ www.oeko.de