GLOBIOM Model

General description

The Global Biosphere Management Model (GLOBIOM)[1] has been developed and is used at the International Institute for Applied Systems Analysis (IIASA). In the context of EUCLIMIT IIASA is applying the model to assess biomass availability and supply as well as impacts of biomass use on ecosystems.

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. GLOBIOM covers 50 world regions of which 27 are the individual EU Member States (see Table 1). 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. The model simulates competition for land between different uses driven by price and productivity changes.

Table 1: Disaggregation of GLOBIOM world regions. The listed 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.

GLOBIOM world region	Disaggregation
ANZ	Australia, New Zealand
Brazil	
Canada	
China	
Congo Basin:	Cameroon, Central African Republic, Congo Republic, Democratic Republic of Congo, Equatorial Guinea, Gabon
EU27, each country is treated as separate region	EU Baltic: Estonia, Latvia, Lithuania EU Central East: Bulgaria, Czech Republic, Hungary, Poland, Romania, Slovakia, Slovenia EU MidWest: Austria, Belgium, Germany, France, Luxembourg, Netherlands EU North: Denmark, Finland, Ireland, Sweden, United Kingdom EU South: Cyprus, Greece, Italy, Malta, Portugal, Spain
Former USSR	Armenia, Azerbaijan, Belarus, Georgia, Kazakhstan, Kyrgyzstan, Moldova, Russian Federation, Tajikistan, Turkmenistan, Ukraine, Uzbekistan
India	
Japan	
Mexico	
Middle East and North Africa	Algeria, Bahrain, Egypt, Iran, Iraq, Israel, Jordan, Kuwait, Lebanon, Libya, Morocco, Oman, Qatar, Saudi Arabia, Syria, Tunisia, United Arab Emirates, Yemen
Pacific Islands	Fiji Islands, Kiribati, Papua New Guinea, Samoa, Solomon Islands, Tonga, Vanuatu
RCAM	Bahamas, Barbados, Belize, Bermuda, Costa Rica, Cuba, Dominica, Dominican Republic, El Salvador, Grenada, Guatemala, Haiti, Honduras, Jamaica, Nicaragua, Netherland Antilles, Panama, St Lucia, St Vincent, Trinidad and Tobago
RCEU	Albania, Bosnia and Herzegovina, Croatia, Macedonia, Serbia-Montenegro
ROWE	Gibraltar, Iceland, Norway, Switzerland
RSAM	Argentina, Bolivia, Chile, Colombia, Ecuador, Guyana, Paraguay, Peru, Suriname, Uruguay, Venezuela
RSAS	Afghanistan, Bangladesh, Bhutan, Maldives, Nepal, Pakistan, Sri Lanka
RSEA OPA	Brunei Daressalam, Indonesia, Singapore, Malaysia, Myanmar, Philippines, Thailand
RSEA PAC	Cambodia, Korea DPR, Laos, Mongolia, Viet Nam
South Africa	

[1] Documentation of the GLOBIOM model can be found at www.globiom.org.

South Korea	
Sub Saharan Africa	Angola, Benin, Botswana, Burkina Faso, Burundi, Cape Verde, Chad, Comoros, Cote d'Ivoire, Djibouti, Eritrea, Ethiopia, Gambia, Ghana, Guinea, Guinea Bissau, Kenya, Lesotho, Liberia, Madagascar, Malawi, Mali, Martinique, Mauritania, Mozambique, Niger, Nigeria, Rwanda, Sao Tome Principe, Senegal, Seychelles, Sierra Leone, Somalia, Sudan, Swaziland, Tanzania, Togo, Uganda, Zambia, Zimbabwe
Turkey	
United States of America	

GLOBIOM disaggregates available land into several land cover/use classes that deliver crops or raw materials for wood processing, bioenergy processing and livestock feeding. Figure 1 illustrates this structure of different land uses, processes, and the commodities produced. 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). Detailed definitions of these types can be found in Table 2. Most of the disaggregation is done based on available national or subnational datasets. Some disaggregation is calculated in GLOBIOM, e.g. the split into managed and unmanaged forest depending on the productivities and FAOSTAT data.

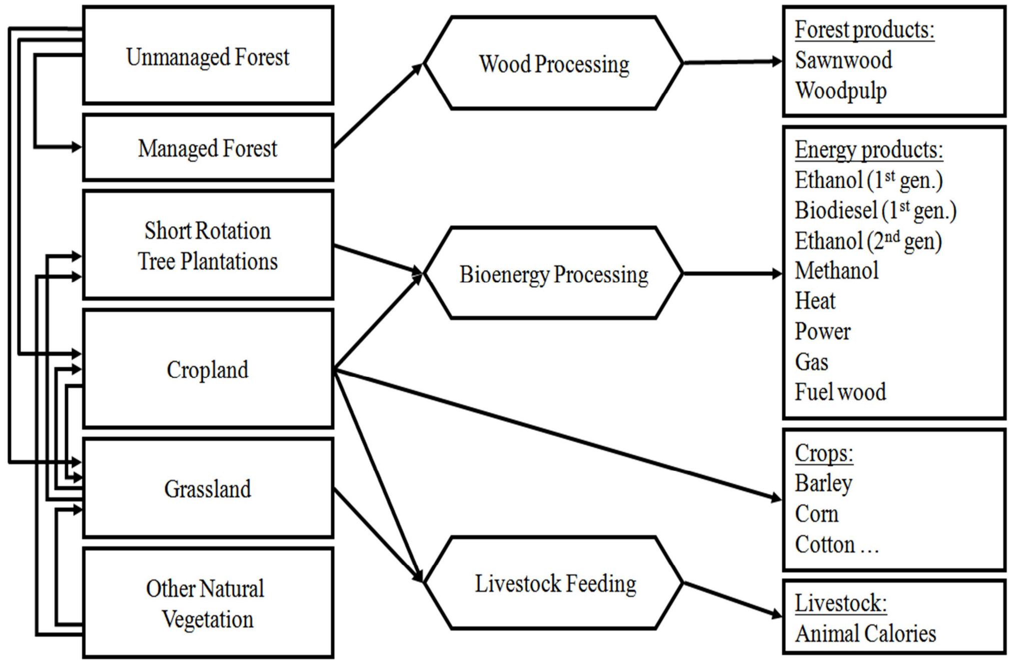

Figure 1. GLOBIOM land use and product structures (Havlík et al, 2011). Note: The arrows on the left represent the direction where a given land use/cover type can expand given the current constraints in the model.

The global agricultural and forest market equilibrium for the commodities listed to the right in Figure 1 is computed by choosing land use and processing activities to maximize welfare (i.e. the sum of producer and consumer surplus) subject to resource, technological, and policy constraints. Production costs account for operational costs, the land rent, and water costs. Labour cost is not represented explicitly in the current version. 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, i.e. determined by the model for respective aggregated world regions. Imported and domestic goods are assumed to be identical (homogenous), but the modelling of trade does take into account transportation costs and tariffs. "Homogenous products" means that consumers do not value differently domestic products compared to imported products – e.g. imported wheat has the same value as domestically produced wheat. However, all the trade flows are indexed by the region of origin and region of destination, which enables to apply even bi-lateral trade arrangements.

Table 2: Land cover/use types in GLOBIOM.

Name	Description
Cropland	GLOBIOM covers 18 major crops, which represented about 80 % of the 2007 global harvested area. Four management systems are considered (irrigated, high input – rainfed, low input – rainfed and subsistence) corresponding to the IFPRI crop distribution data classification.
Grassland	Managed grassland used for livestock production.
Forest, managed	Managed forests are used for wood production. Five primary products can be harvested from managed forests: saw logs, pulp logs, other industrial logs, firewood, and energy biomass.
Forest, unmanaged	Forest reserve currently not harvested.
Forest, protected	Protected forest not available for wood supply.
Short rotation plantations	The energy biomass, which can come from managed forest and short rotation tree plantations can be used in bioenergy chains for polyproduction of ethanol, methanol, heat and power, and biogas mixes.
Other natural vegetation	Other land that can be converted to managed grassland or short rotation plantations.

GLOBIOM includes accounting for greenhouse gas emissions and sinks from agricultural and forestry activities. This includes for example accounting for N_2O emissions from fertiliser use whose intensity in turn depends on the management system. 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. 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 (i.e. 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.

The model is recursive dynamic in the sense that changes in land use made in one period (typically 10 years) alter the land availability in the different categories in the next period. Land use change is thus transmitted from one period to the next.

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. Concrete species currently considered in second generation technologies are Eucalyptus, Acacias, Poplar, Willow but also forestry and forest industry residues.

Land potentially available for bioenergy is estimated by excluding areas unsuitable due to their level of aridity, temperatures, elevation and population density from total arable land area (grassland, cropland, 'other natural vegetation', see Havlík et al. (2011)). The demand for food and other biomass uses is limiting the expansion of bioenergy production on these areas. Depending on the scenario the food demand is allowed or not to vary in response to bioenergy targets. Competition is created either through changed prices, or through both changed prices and quantities.

Input data

Land resources and their characteristics are the fundamental elements of our modelling approach. In order to enable global bio-physical process modelling of agricultural and forest production, a comprehensive database has been built (Skalský et al. 2008), which contains geo-spatial data on soil, climate/weather, topography, land cover/use, and crop management (e.g. fertilization, irrigation). The data were compiled from various sources (FAO, ISRIC, USGS, NASA, CRU UEA, JRC, IFRPI, IFA, WISE, etc.) and significantly vary with respect to spatial, temporal, and attribute resolutions, thematic relevance, accuracy, and reliability. Therefore, data were harmonized into several common spatial resolution layers including 5 and 30 Arc minutes as well as country layers. Subsequently, Homogeneous Response Units (HRU) have been delineated by geographically clustering according to only those parameters of the landscape, which are generally not changing over time and are thus invariant with respect to land use and management or climate change. At the global scale, we have included five altitude classes, seven slope classes, and five soil classes. In a second step, the HRU layer is intersected with a 0.5° × 0.5° grid (representing an area of about 10x10 to 50x50 km) and country boundaries to delineate Simulation Units (SimU) which contain other relevant information such as global climate data, land category/use data, irrigation data, etc. For each SimU a number of land management options are simulated using the bio-physical process model EPIC (Williams 1995; Izaurralde et al. 2006). For the bulk of global crop production four management systems are currently available in GLOBIOM; these are irrigated, high input – rainfed, low input – rainfed and subsistence management. The systems are constrained to the supply units where they have been observed in the base year but their proportions can change. Climate change impacts on crop growth can be incorporated by running respective scenarios with EPIC.

The HRU concept (Skalský et al. 2008) assures consistent aggregation of geo-spatially explicit bio-physical impacts in the economic land use assessment. Each land related activity and all land resources are currently indexed by country, altitude, slope, and soil class. The information relevant to the 0.5° × 0.5° grid layer has been averaged to keep the model size and computational time within reasonable limits. This is also the level at which impacts of biomass use on ecosystems can be assessed in the model.

Driver data

As GLOBIOM is a partial equilibrium model, not all economic sectors are modelled explicitly. Instead, several parameters enter the model exogenously, 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 consumption per capita (i.e. calories in the process to satisfy human consumption based on projections according to FAO 2006). Assumptions on GDP, population growth and calorie consumption per capita are the underlying driver of the model dynamics. Population and GDP influence demand through GDP elasticities. The model assumes an exogenous GDP, compared to other models like CGE, or macroeconomic growth models which assume an endogenous GDP. Effects of the agricultural and forestry sector on GDP are considered to be rather small on high and middle income economies but cannot be ignored for some low income economies.

The base year for the model is the year 2000, the model horizon can be up to 2050. 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 improvement. Exogenous yield growth has featured in earlier versions of

GLOBIOM as the same everywhere, now it is differentiated by crop and region. Only a part of the yield increase is exogenous in GLOBIOM and can be controlled. Endogenous yield increases due to system or location switches are possible. The option to shift between management systems as well as the relocation of crops to more productive areas also provides for regional average yield changes.

Policies that GLOBIOM considers are biofuel targets as well as the most important sustainability criteria of biofuel policies can be modelled. And probably much more but it is easier to discuss concrete examples rather than try to make a list here which would be necessarily incomplete. Management changes are introduced on the basis of relative profitability. Major limiting factor for such changes is land availability. However, the model assumes a certain rigidity in the system limiting the speed at which some changes may happen and policies are implemented.

Links to other models

EPIC

GLOBIOM is closely linked to EPIC. By using results of this agriculture model that provides biophysical parameters and constraints to the economic land use model, GLOBIOM can deliver more dynamic estimates of net GHG emissions from cropland and grazing land management. It also enables GLOBIOM to consider effects of global climate change on crop yields.

G4M

Similar to EPIC in the agricultural sector, the detailed forest model G4M provides GLOBIOM with biophysical constraints of the forestry sector. This includes variables regarding biomass stocks, carbon stocks, harvestable wood, growth rates etc. GLOBIOM typically delivers to G4M estimates of commodity prices relevant for G4M (i.e. wood and land) and on the development of wood demand/production per GLOBIOM region.

CAPRI

CAPRI combines external projections, technical restrictions and information included in historical time series to develop projections of the agricultural sector in EU. Such detailed baseline information on areas and production can be used by GLOBIOM that lacks detail for e.g. permanent crops and detailed land use policies. CAPRI can on the other hand benefit from information from GLOBIOM on global drivers as e.g. food and fibre demand, and resulting areas of the various land uses. This makes the two models complementary for modelling agricultural activities in EU countries.

PRIMES/POLES

GLOBIOM is not covering the energy sector and is therefore dependent on external projection of bioenergy demand. Bioenergy projections from the POLES model (for regions outside Europe) and the PRIMES model (for EU 27 countries) supply regional biomass demand taken up by GLOBIOM in four categories: heat and power (BIOINEL), direct biomass use i.e. for cooking (BIOINBIOD) and liquid transport fuel use (BFP1 and BFP2 or first and second generation biofuels, respectively). These demands GLOBIOM typically implements as target demands or minimum demand constraints. This means that exogenous bioenergy targets are assumed to be reached at any price (i.e. bioenergy demand is assumed to be price inelastic).

Recent applications

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. 2011). 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).

References

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