

Title

Integrated Multi-scale Modeling Framework for Assessment of Land-use Related Challenges under Global Change

Authors

Petr Havlík¹, Hugo Valin¹, Aline Mosnier¹, Nicklas Forsell¹, Stefan Frank¹, David Leclère¹, Amanda Palazzo¹, Tatiana Ermolieva¹, Mykola Gusti^{1,2}, Juraj Balkovič¹, Rastislav Skalský¹, Erwin Schmid³, Mario Herrero⁴, Florian Kraxner¹, Michael Obersteiner¹

Affiliations list

¹ International Institute for Applied Systems Analysis, Laxenburg, Austria; ² Lviv Polytechnic National University, Lviv, Ukraine; ³ University of Natural Resources and Life Sciences, Vienna, Austria; ⁴ Commonwealth Scientific and Industrial Research Organisation, Brisbane, Australia

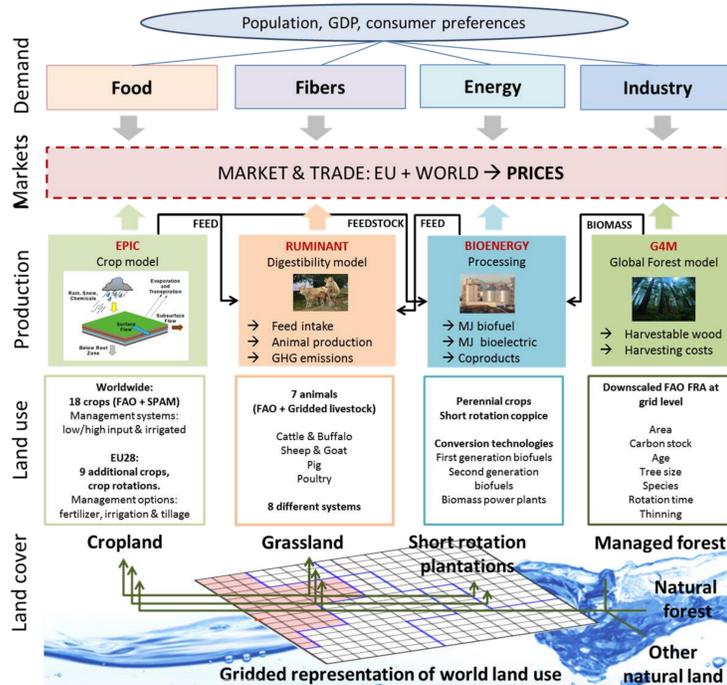
Abstract

Land is the cornerstone of many of the sustainability challenges the world is facing. About 800 million people are still undernourished today, mostly in rural areas. Agriculture will need to expand production by 60% by 2050 to satisfy future food demand but is anticipated to be the sector most directly hit by climate change. At the same time, agriculture, forestry, and land-use change are responsible for 25% of global anthropogenic greenhouse gas (GHG) emissions and these sectors are also key to achieving climate stabilization, as they can provide negative emissions through afforestation and bioenergy production with carbon capture and storage. Advanced system analysis tools are required to capture the multiple dimensions of these challenges: the global partial equilibrium model of agricultural and forest sectors, Global Biosphere Management Model, developed at IIASA, represents the state of the art in model linking across sectors, disciplines, and spatial scales. This model integrates information from a 1x1 km grid where the land characteristics and climate are defined, up to 30 regional aggregates where the international trade is represented. Spatially explicit production activities are defined through Leontief production functions representing the input-output relationships of a large set of production systems/technologies. Crops, grass, livestock, and forest systems are parameterized through biophysical models which capture overall production and environmental impacts such as carbon and nitrogen balances, water use, or GHG emissions. The model can also be used for market foresight, integrated assessment of climate change impacts and adaptation, or for assessment of mitigation options by providing to energy system models, such as Model for Energy Supply Strategy Alternatives and their General Environmental Impact (MESSAGE) at IIASA, economic information on abatement potential through emissions reduction, carbon sequestration and bioenergy production. More specific applications of the model have also been applied at global, regional and even national level, and validated by numerous publications.

Introduction

Land is the cornerstone of many of the sustainability challenges the world is facing today.

- About 800 million people are still undernourished, mostly in rural areas.
- Agriculture will need to expand production by 60% by 2050 to satisfy future food demand but is anticipated to be the most directly hit sector by climate change.
- Agriculture, forestry and land use change are responsible for 25% of global anthropogenic GHG emissions: these sectors are also key to achieve climate stabilization.
- Advanced systems analysis tools are required to capture the multiple dimensions of these challenges: the global partial equilibrium model of agricultural and forest sectors, GLOBIOM, developed at IIASA, represents the state of the art in model linking across sectors, disciplines and spatial scales.



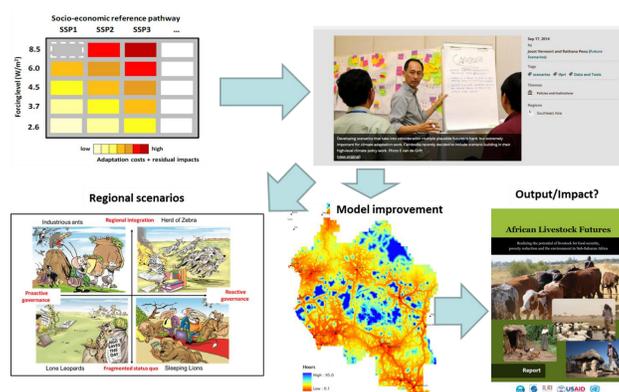
GLOBIOM

- Global model with 30 regions linked by bilateral trade flows
- Agricultural, wood and bioenergy markets
- Base year is 2000, simulations for every 10 year time step, up to 2030/2050/2100
- Production technologies a la Leontief specified by production system and grid cell
- Detailed spatial resolution (>200k pixels)

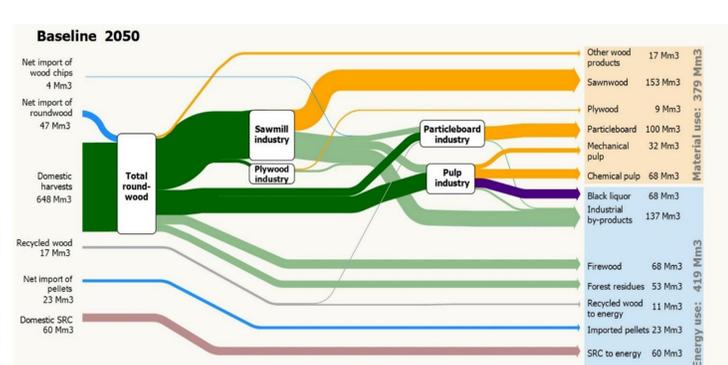
Global and regional foresight

- The GLOBIOM team actively participates in community efforts on development and quantification of the new generation of IPCC scenarios.
- These scenarios and their derivatives were for instance used in OECD (2015) for future food and agricultural sector foresight. But appear useful also for regional development scenario work (Vervoort et al., 2013; Herrero et al., 2014)
- As means of validation, GLOBIOM model participates in several model intercomparison projects, such as AgMIP (Valin et al., 2014)
- In an upcoming study for the European Commission, GLOBIOM is used to analyse the resource efficiency implications of alternative EU energy policies at high level of sectoral disaggregation (Lauri et al., 2014).

From global to local scenarios



Integrated but detailed sectoral representation

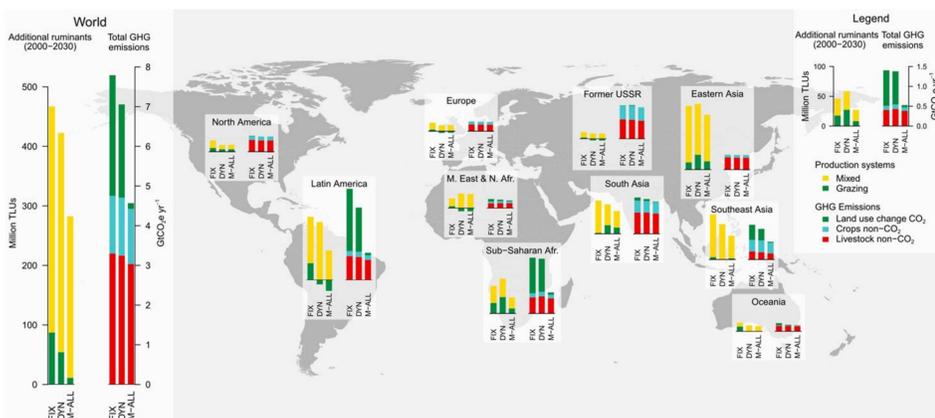


Source: CCAFS, UN Secretariat, and Mosnier et al., 2012, ERE

Source: Report to European Commission, forthcoming

Climate change mitigation

Livestock production systems changes and global GHG emissions



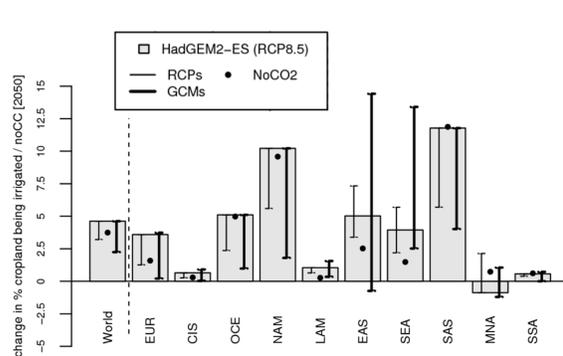
Source: Havlík et al., 2014, PNAS

- Livestock are responsible for 12% of anthropogenic GHG emissions. Havlík et al. (2014) show that transitions toward more efficient production systems would decrease emissions by 736 MtCO₂e per year (see Figure on the left).
- Major productivity gaps remain that could be exploited to supply more food on existing agricultural land and at lower costs. Valin et al. (2013) show that closing yield gaps by 50% for crops and 25% for livestock by 2050 would decrease agriculture and land use change emissions by 8% overall, and by 12% per calorie produced. However, the outcome is sensitive to the technological path.
- Soil carbon sequestration through improved management of agricultural land is considered a promising mitigation option. However for Europe, Frank et al. (2015) show that only limited contributions from European cropland should be expected for climate change mitigation.
- Emissions from tropical deforestation represent about 12% of global emissions. GLOBIOM has been used to explore potential deforestation reduction strategies in Brazil and in the Congo Basin (Mosnier et al., 2012). For Brazil, Cohn et al. (2014) estimate that significant reduction of global GHG emissions could result from pasture intensification.

Climate change adaptation

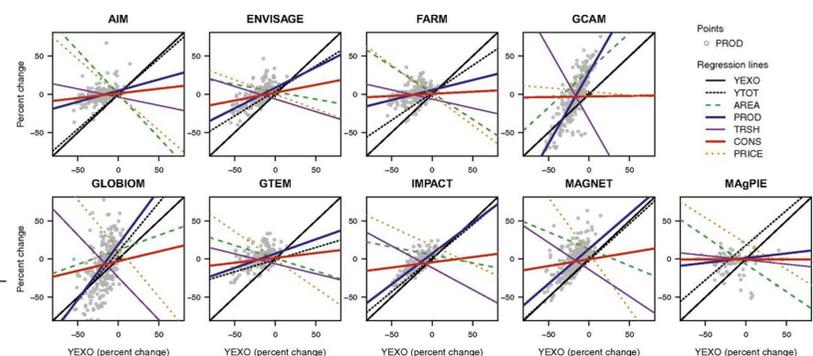
- Global crop yield losses due to climate change could be as large as 5% by 2030 and 30% by 2080.
- The impact on food prices in Africa could be as high as 12% in 2030 and 70% by 2080, a region where food consumption of the poorest amounts to 60% of spending.
- GLOBIOM offers insight into how much transformation is required from agricultural systems, how robust such strategies are, and how we can defuse the associated challenge for decision-making (Leclère et al., 2014).
- Adaptation responses can be field level but also rely on larger scale adjustments, such as change in cropland area, production reallocation between sectors and regions, and change in demand for food, feed and other uses (Nelson et al., 2014, Mosnier et al., 2013).

Impact of climate change on the share of the cropland which is irrigated



Source: Leclère et al., 2014, ERL

Comparison of the impact of climate change on agriculture assessed by different models



Source: Nelson et al., 2014, PNAS