FABIO: Food and Agriculture Biomass Input-Output model

Tracing global biomass flows at an unprecedented level of product and country detail

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This Brief introduces FABIO, a new model that analyses biomass flows and embodied land along global supply chains in 191 countries, covering 130 agriculture and food products in physical and more than 50 industrial products in monetary terms over the last three decades. FABIO is the starting point for producing spatially explicit biomass flow models in FINEPRINT, integrating sub-national production data, global crop maps and transport models. FABIO scripts and data are available at our GitHub portal.

Introduction

Against the background of continued high dependency on fossil fuels and accelerating climate change, many countries have started efforts to transform their economies towards an increased use of biobased energy, materials and technologies. 'Bioeconomy' strategies are being designed and implemented at various national and sub-national levels.

However, there is an intensifying debate about the limits of a bio-based transformation to contribute to sustainable development in terms of a low-carbon, resource efficient economy. Evidence is rising that the environmental impacts and degradations of ecosystems caused by expanding bioeconomies threaten the maintenance of basic life-supporting ecosystem functions [1]. It is therefore of crucial importance to understand the trade-offs between different uses of biomass, including food, feed, and non-food industrial products, such as textiles and biofuels. Further, the global implications of national bioeconomy strategies need to be taken into account through considering indirect impacts caused by international trade of biomass-based products.

Primary crops are connected to final consumption by networks of processes and actors that convert and distribute material and energy goods. These networks form the metabolic structures of an economy. Most models developed so far use monetary data to investigate these structures. However, data issues and assumptions of these models limit the robustness of assessments of global biomass flows and embodied land. These relate, for example, to the aggregation of products with very different material intensities into one assumingly homogeneous economic sector or to the allocation of physical flows along monetary structures assuming equal value-to-weight ratios for all flows of a specific product. Therefore, revealing the physical structures of these conversion and distribution networks is essential to understand the characteristics, drivers and dynamics of the biomass metabolism of societies.

The basic structure of FABIO

FABIO, the Food and Agriculture Biomass Input-Output model, allows analysing biomass flows and embodied land along global supply chains at an unprecedented level of product and country detail. In its core, FABIO contains a set of supply and use tables in physical units, which are linked through bilateral trade data. This physical core is extended by monetary information on the structure of the global economy in case product supply chains cannot be modelled to the final consumer in physical units only. FABIO thus operates in a hybrid, i.e. mixed-unit, supply-use framework that combines physical data from the UN Food and Agriculture Organization (FAO) with monetary data from EXIOBASE 3 [2] (see Figure 1).

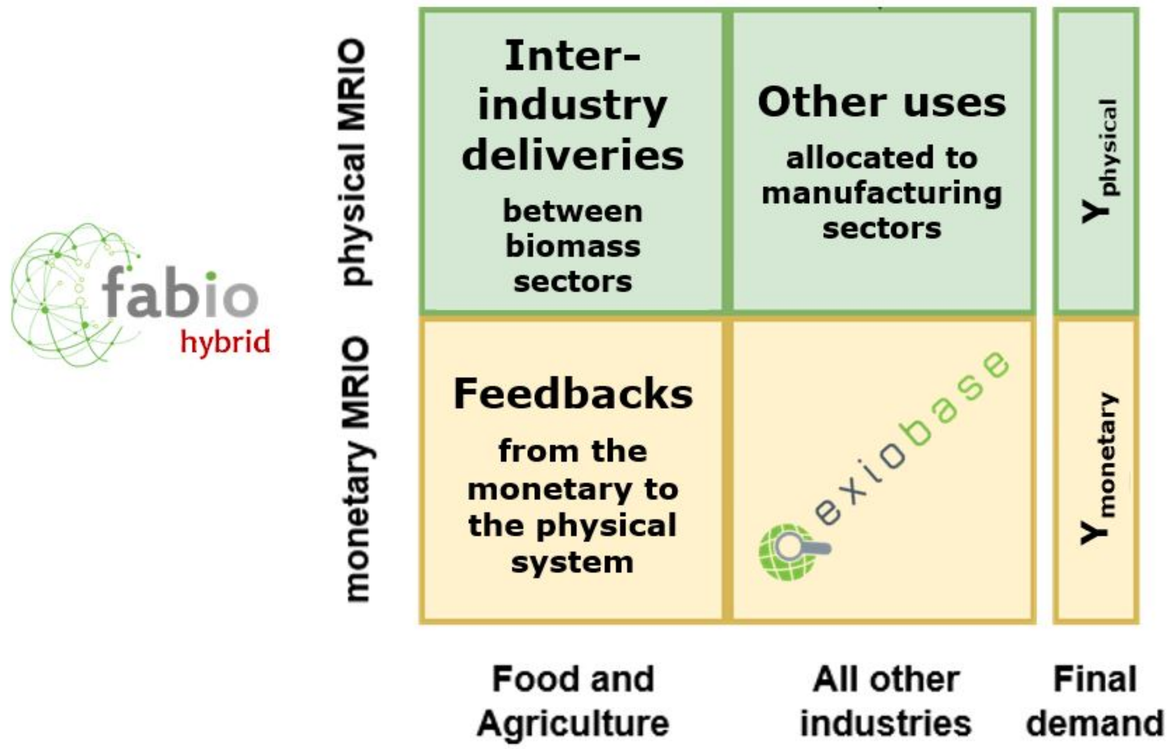

Figure 1: Model structure of FABIO

The FABIO model delivers detailed physical supply chain information for 130 raw and processed agricultural and food products and additionally covers more than 50 industrial products in monetary units. The model is implemented for 191 countries and currently covers the time span from 1986 to 2013, with regular updates being planned for the future.

Creating physical supply, use and input-output tables for biomass

FABIO integrates agricultural production, trade and use data for primary and processed agricultural and food products, provided by the FAO Statistical Database. The FAO's commodity balance sheets (CBS) provide time series data on the supply and utilisation of agricultural products. They are balanced in terms of physical quantities by matching the supply from domestic production and imports with the various use types, i.e. domestic use for food, feed, processing, seed, waste and other uses, stock changes as well as exports, and allow constructing physical supply and use tables (PSUTs). Combined with international trade data, the flows of raw and processed agricultural and forestry products circulating through the global economy can be documented.

In a first step, we define the products and processes according to the CBS classification. Second, we populate the supply table, which is straight-forward, as production data is available from FAOSTAT and can be attributed to a specific process for each product. We then identify the input structure of the processes and fill the use table. Some processes require just one input, such as rapeseeds for rapeseed oil production or sugar cane for sugar production. These intermediate uses of inputs are estimated using technical conversion factors (TCF) provided by the FAO. To determine the feedstocks used for the production of alcoholic beverages and ethanol, we apply a constrained least-squares optimisation, minimizing the difference between available inputs and reported outputs for each process, constrained to the conversion efficiencies given by the TCFs. Feed inputs to the livestock processes are quantified reproducing the feed balances described by Bouwman et al. [3]. In a final step, we trade-link the resulting national PSUTs and convert them into symmetric multi-regional physical input-output tables (mrPIOTs) applying the industry technology assumption. Thereby, inputs are allocated to the outputs of processes according to their share in the total output.

According to the CBS database, final use is defined as food use or industrial use. Biomass embodied in manufactured products such as cotton in textiles or maize in ethanol, thus, can only be further traced downstream by coupling the mrPIOTs with a monetary MRIO model. In a last step, we therefore trace upstream flows of embodied biomass through the economy along monetary supply chains covered by the MRIO system EXIOBASE, which disaggregates 200 different products and product groups [2].

Applications of FABIO

The FABIO model allows addressing a wide-range of important questions for currently ongoing 'bioeconomy' debates in countries around the world.

- **Detailed composition and drivers of global biomass consumption**: FABIO exposes the detailed composition and origin of renewable raw materials and related land embodied in a wide range of final products. Applying decomposition methods reveals the main driving factors, such as technology or feed mix, supply structure or affluence, responsible for changes in biomass consumption and related supply chains in different world regions over the past three decades. This assessment delivers an important empirical basis for identifying potential future trade-offs arising from the increased competition for global biomass and for designing actions by business and policy makers to reduce competing demands.

- **Footprints of non-food products**: Applying the FABIO model for the first time allows separately analysing the category of non-food industrial products, which is the most rapidly expanding part of the global cropland footprint. These non-food products include, for example, biofuels, textiles, and feedstocks of the chemical industry. Results from FABIO illustrate that cropland demand is increasingly driven by other than traditional food value chains, including more complex or completely new value chains that emerge in response to new biomass applications [4].
- **Boost the detail of economic simulation models**: FABIO can be used as a stand-alone tool to perform scenario calculations in the tradition of IO analysis, addressing questions such as: What would be the impact on production and land use in all countries if final consumption of a specific product in a specific country would increase by x%? However, these analyses assume that physical shares in production inputs are constant, e.g. that beef producers in one country use a fixed amount of soy cake from another country per ton of produced beef. Economic models, such as CGE and econometric models, can be combined with FABIO in order to introduce dynamic changes, such as altered bilateral trade shares based on relative price changes. At the same time, FABIO can strengthen existing economic simulation models by contributing additional product and country detail.

Spatially explicit biomass flow models

FABIO is very well suited to trace international flows of agriculture and food products and to derive land use footprints at the country level. But environmental and social conditions vary significantly over time and space, demanding footprint models to move from the national to a much more detailed spatial level. We are therefore currently extending FABIO by subnational data, thereby boosting the level of spatial detail from currently 191 countries to thousands of subnational regions such as states, provinces or municipalities, depending on data availability.

We further downscale the resulting subnational footprints for some major crops to the level of 5 arc minute grid cells (around 10 km x 10 km at the equator) using the spatial distribution of 42 crops provided by the Spatial Production Allocation Model (SPAM) v3.2 [5]. We allocate the footprint in each region to the geographically corresponding cells within that region, using the harvested area reported by SPAM to weight the allocation of the footprint into the SPAM grid cells. In order to consider sub-regional differences in the export shares and structures, we further extend this approach by a transport model, which determines cost-efficient sub-regional transport routes.

To sum up, we apply three steps of downscaling from the national level to the grid cell: 1. We use available data to build subnational PSUTs for thousands of regions. 2. We determine cost-efficient sub-regional transport routes. 3. We allocate the footprint in each sub-regional area to the geographically corresponding cells within that region, using a spatially explicit harvested area product.

Open science

All R scripts and auxilliary data to build the FABIO model are freely available to the research community in a format complying with copyright rules of the data providers via our GitHub portal, in order to foster global efforts to further develop and enhance the data basis for MRIO analysis. We are convinced that openness, transparency and sharing contributes to the advancement of science (see FINEPRINT Brief No. 1) and invite researchers to test and scrutinise our codes and results.

Citation

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