ENVIRONMENTAL AND ECONOMIC ACCOUNTING FOR THE GERMAN AGRICULTURAL SECTOR

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Abstract

How can we estimate the negative externalities of agriculture at the national level, and attribute these to specific production activities and outputs? The paper presents a method that calculates the mass flow in the whole agricultural sector including inputs from other sectors, and that allows to analyse resource use and emissions, e.g. of greenhouse gases.
Data inputs are the German economic accounts for agriculture, farm structural survey and market statistics, as well as environmental statistics. In the framework of the German agricultural sector model RAUMIS, material flows within the agricultural sector are described, as well as inputs from other German sectors and imports. Through a process-analytical approach, all information is integrated and matrices of resource use and emissions for all agricultural production activities are generated. A monetary allocation is used to identify the respective activities that are responsible for emissions, including indirect emissions in upstream sectors. Related to the market output, cumulative emissions per unit of output can be computed. Results for the period from 1995 to 2007 show the trend of resource uses and emissions for the national average values of important commodities such as milk and meat.

1 Introduction

The mitigation of greenhouse gas (GHG) emissions is becoming a priority of environmental policies and the legislation at the national and European level (EC, 2002). For this purpose, we must identify the GHG sources and better understand the interrelation between emissions at different points in the production. Reliable data and broadly accepted accounting procedures are needed to provide a robust basis for decision-making processes.

The purpose of the presented contribution is to introduce an input-output analysis for the description of resource use and emissions and its application to the German agricultural sector. The most important parts of the analysis are the material and energy flows, which are connected to the economics as well as to emissions arising from the production processes. The comprehensive description of the agricultural sector offers the basis for the calculation of ecological efficiency indicators based on physical input/output or emission/output relations. We use this algorithm for detecting relevant emission sources and identifying eventual causes of emissions within the German agri-sector and the external suppliers such as the chemical sector and inputs imported from abroad.

2 Materials and Methods

2.1 Framework

The System of Integrated Environmental and Economic Accounting (SEEA, UN et al., 2003) can be used to quantify and analyse interdependencies between economic systems and the environment. SEEA constitutes a satellite system added on the national economic accounts. As one element of SEEA, the analysis of material and energy flows, resource use and emissions (including CO_2-footprint) is an approach at the national level comparable to Life Cycle Assessment (LCA) methods applied to particular production chains.

On behalf of the Federal Statistical Office responsible for the German SEEA (Destatis, 2009; Schoer, 2006), we are involved in an explorative project for disaggregating the agricultural sector as part of the national environmental accounts (Osterburg and Schmidt, 2008; Schmidt and Osterburg, 2009). The main objective is to provide a more detailed depiction of specific production activities and main outputs of the sector while maintaining full consistency with data of the national monetary and physical accounts, and to emissions in official inventories. Calculations are based on the German sector model RAUMIS (regionalised agricultural and environmental information system), which is used for integration of different data sources and describes the sector in a process-analytical approach. The complete and consistent physical data framework describes production processes and input-/output-relations, including data on intermediary products like feed, manure and young livestock. A focus of the analysis is the calculation of total resource use and emissions, calculated on the base of the physical and monetary input-output tables (IOT) and its inverse matrices. For analysis of multi-input-/multi-output agricultural production systems, allocation procedures are based on monetary I/O-relations because of the financial dependency between the production chain and the use of products (Huppes and Schneider, 1994). This approach corresponds to the technical report ISO/TR 14049 that suggests an economic allocation in the case of fixed coupling of outputs (e.g., main output and by-products of dairy production). In addition, the largest parts of the emissions are assigned to the main product with the highest monetary value of the activity (milk production). Indeed, the co-products are also marketed, but with an impact on production decisions and income (e.g., meat of dairy cows) depending on the market price. Economic allocation of emissions in the production chain reflects the respective impact on production decisions. Co-products without a reported monetary market value get an equivalent (e.g., replacement cost of organic manure compared to mineral fertilizer). If a product is below a monetary limit of 1 % (e.g., hide) it will not be taken into account.

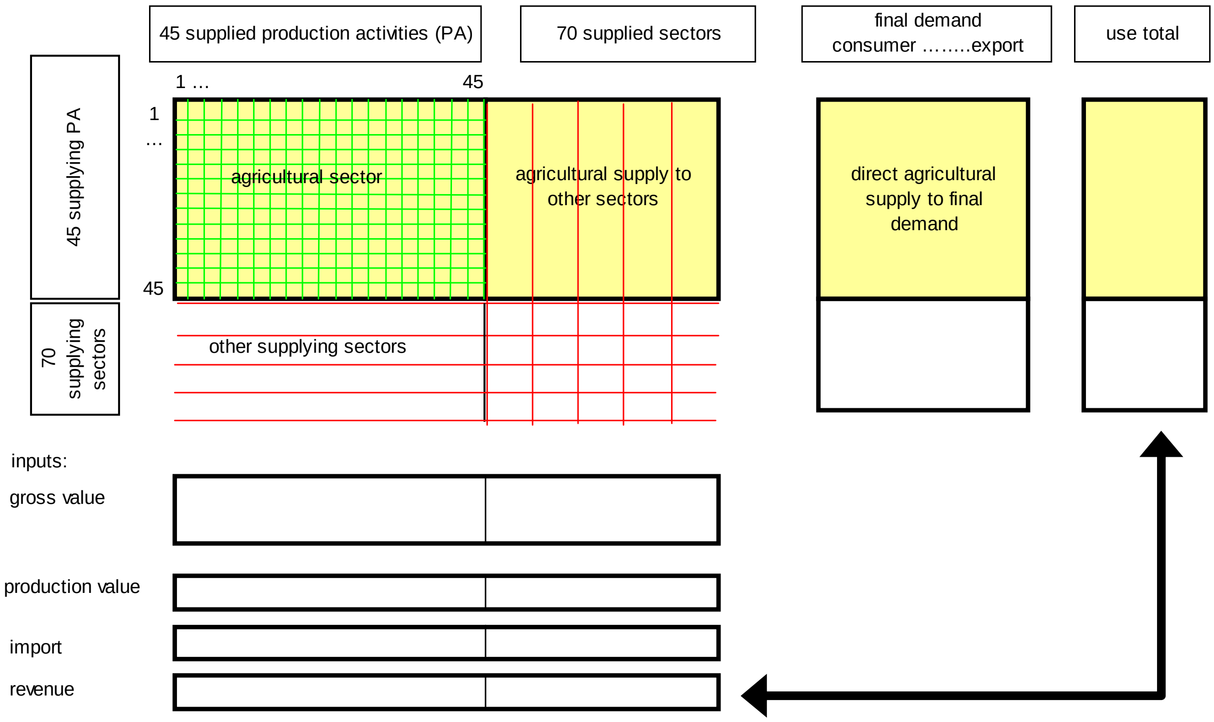
2.2 Data

The simulation is based on the German economic accounts, agrarian structural data and other statistics of the Federal Statistical Office (Destatis) and the Federal Ministry of Food, Agriculture and Consumer Protection (BMELV), as well as on technological and management parameters, derived from farm calculation data or estimated on the base of farm bookkeeping data. Another important data source are international environmental reports delivering data on gas emissions (UBA, 2009) and nitrogen balances (OECD, 2001).

A major task was the integration of the various data sources in a consistent system in which we consider all monetary dimensions and physical parameters. Data from the agricultural accounts (LGR) and international reports had the uppermost priority. The breakdown of these figures to the level of single production activities had to be adapted for the reported years (1995, 1999, 2003 and 2007).

2.3 Input-Output-Table

Core element of the input-output analysis is the square matrix, which contains all 45 production activities (e.g. crop and fodder production, dairy cows and fattening pigs) in the first column (supplying processes) as well as in the headline (processes supplied). Figure 1 shows the table structure of the agricultural relations and the peripheral sectors (70 other supplying and supplied sectors and the final demand). The intra-sectoral exchange of goods between different agricultural activities is thereby systematised as well as the inter-sectoral relations between the agricultural sector and other economic sectors.



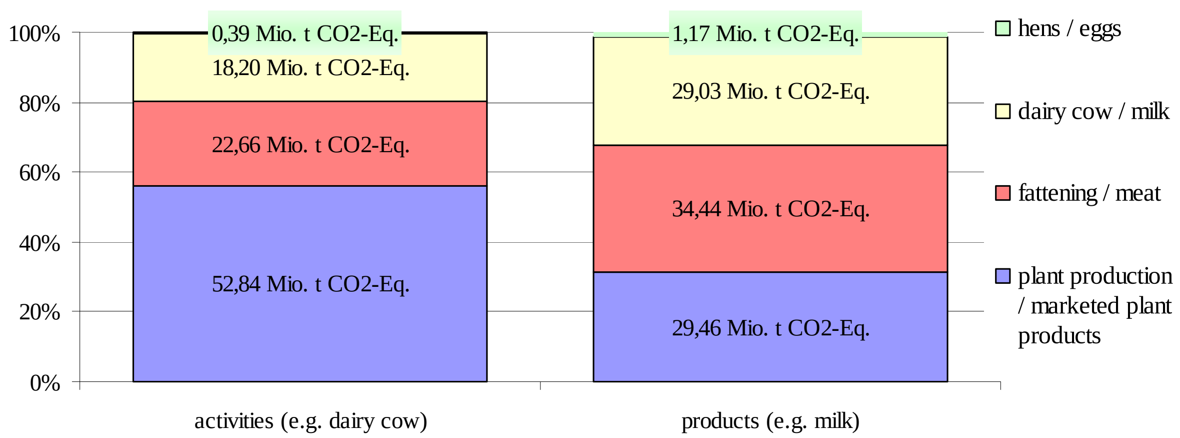
Source: Schmidt und Osterburg, 2009

Figure 1: Pattern of the Environmental-Economic Accounting

The module ´agriculture and environment´ of the German SEEA focuses on the production activities of the agricultural sector. This IOT lists all exchanges of intermediate inputs within agriculture and inputs from other sectors, in physical, as well as in monetary units (tonne or euro). The inverted matrix of the IOT, called ´Leontief inverse´, allows the calculation of the direct and indirect inputs for of all producers and their transfer to cumulated output units. The Leontief inverse of the monetary matrix and a subsequent multiplication with a load vector reveals the product specific charges. This results in a load per agricultural product, such as, for example, raw milk and meat at farm gate. Load vectors are so-called satellite systems, which are complementary to the monetary IOT adding physical data on resources or emissions. The division of the total values with the production amount reveals the specific load per unit (e.g., CO_2/kg). Besides CO_2 emissions, we consider also the methane and nitrous oxide emissions. All GHG emissions are aggregated to CO_2-Equivalents ($CO_{2Eq.}$) of global warming potential as cumulative indicator for GHG emissions.

3 Results

The inverse matrix transfers the direct resource uses and emissions that occur in the specific *production activities* ('field and stable') to cumulated results of the agricultural outputs like milk, meat, eggs and plant *products*. Figure 2 presents the results of this reattribution of emissions to the final commodity at farm gate for the 2007 greenhouse gas emissions. Plant production emits more than 50 % of the $CO_{2eq.}$ (left column). Grassland provides forage through grazing or silage. In the activity-based approach, forage production belongs to the plant production. With regard to cumulative emissions of products, emissions of forage production are assigned to the milk and meat products (right column). The marketed plant products of about 30 % represent cereals and root crops for processing as well as energy crops. Emissions of inputs from other sectors and imported fodder are not included in this calculation.



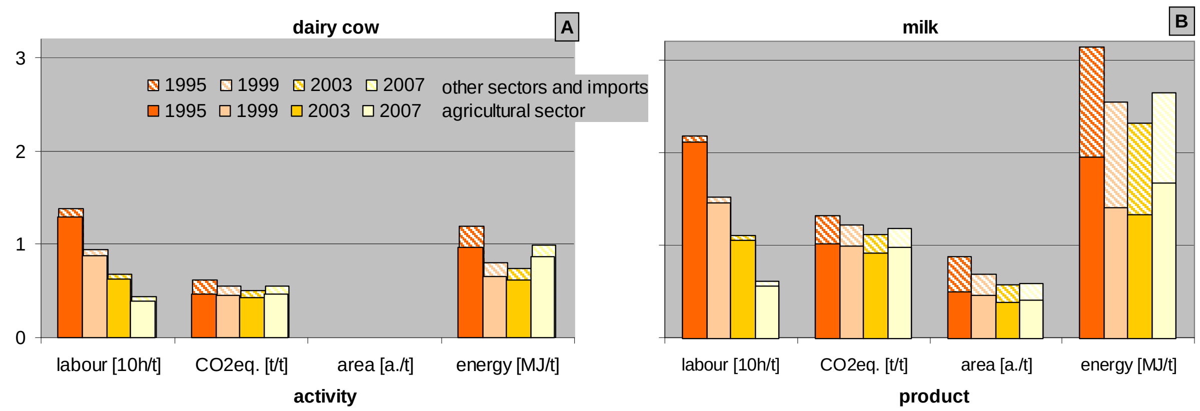
Source: Own illustration

Figure 2: Direct $CO_{2eq.}$ emissions of activities and products of the German agri-sector in 2007

The presented tool generates physical and monetary totals at the sector level for milk, meat, eggs and marketed plant products. A division through the produced quantities, such as million kilograms of milk per year, provides the national average burden per unit of product. Based on these national and sectoral aggregates, we derive an average emission of about 1 kg $CO_{2eq.}$ per kg of raw milk and approximately 0.5 kg $CO_{2eq.}$ per kg wheat. These numbers coincide with results of product-specific LCA studies (Grünberg et al., 2010).

In the next step, we consider inputs from the chemical sector (mineral fertilizers, pesticides) and the impact of feed imports. The imported fodder accounts for about 17 %, calculated in

´grain equivalent units´, and 29 % of the digestible protein of Germany's agricultural sector (BMVEL, 2010). Figure 3 shows some results in detail for milk production.
The columns represent 4 point of times for 1995 - 2007 and the burden of the agricultural sector (full-colour) as well as of the inputs of other sectors and imports (shaded). In the left diagram (A), the resource use (labour, land use, energy) and emissions ($CO_{2Eq.}$) of the activities are displayed. The right diagram (B) shows results of the inverse matrix, which generates the cumulative product specific values. In the case of milk production, there is no direct land use (area in acres [a.] ~ 0.4 Hectares) for dairy cows (area demand of stables is not considered) but for forage cultivation which is displayed in diagram B. As a trend, emissions are consistently decreasing over the years. This means that productivity and ´GHG-efficiency´ rises. An exception in the year 2007 can be explained by below-average yields because of drought in the summer.



Source: Own illustration

Figure 3: Direct and indirect resource use and emissions of milk production in the German agricultural sector plus delivered products from other sectors and imports

Of course, there is a range of uncertainties in the calculation such as the chosen allocation method, but the results are consistent to the official statistical data framework.

4 Conclusion

The described top-down approach analyses the resource use and the emissions of the German agricultural sector considering economic as well as physical data, which we integrate in a consistent model system. We depict the most important processes in an I/O square matrix, which considers all activities of agricultural production.

One important advantage of this method is the consistent calculation of all relevant data, especially of the statistics and international reporting framework, which delivers national average values for agricultural commodities. In spite of a preference for monetary allocation in this analysis, a physical allocation might be advantageous when prices or currencies fluctuate highly in space and time.

At this stage of the development of the agricultural module of the German SEEA, we calculate the resource use and emissions of agricultural products at the farm gate and involve inputs of other sectors and imports.

In the future, we intend to expand the system boundaries towards the food and retail industry including processing, storage and transport. The accounting system also enables the integration of private households and the waste management industry to close the production cycle. Further, we plan a scaling-down of agricultural national accounts into regions and farm types in order to identify scope for GHG mitigation and to connect production activities to specific types of land use and land use change.

Connecting other national SEEA calculations from exporting countries, which supply the German agrarian sector, would also be a future task.

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