Study of cereals flows at local scales: Examples in the Rhône-Alpes région, the Isère département and the SCOT de Grenoble

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The purpose of this article is to put forward the role applied mathematics and computer science could play in the field of ecological accounting and particularly in that of material flow analysis. It is done based on a detailed study on modeling cereal flows at sub-national scales.

Material Flow Analysis at the scale of urban areas, applied to primary materials, half-products and finished products, as well as the understanding of supply chains (production, intermediate transformation, final consumption) are necessary first steps to tackle the analysis of environment impacts. In this perspective, the lack of data at local scale is a serious issue and it is often necessary to find ways of using data from larger geographical levels (*département*, *région* or country). Our study is based on the supply and use balances produced by Agreste[1] at the national level. We display the results using Sankey diagrams because they make it possible to have a compact and complete view of the flows (production, transformation, trade of primary or derived products, and final consumption), while also underlining incoherences.

The national diagram tells us the data we have to look for at sub-national levels. In France, the main use of cereal grains (exception made of exports to foreign countries which represent roughly half of the production) are:

- livestock feed (about 2/3 of interior uses),
- consumption of the food-processing industry: mills, production of breakfast cereals, pasta and couscous, malt, and about half of the starch industry,
- consumption of other industries: distilleries (bioethanol) and the other half of the starch industry.

The per capita final consumption calculated with Agreste and FranceAgriMer data is very close to the figures taken from Insee[2] surveys, which is a way of validating the methodology. In this work, we did not look into the meat industry nor into the trade of meat products. This should be done in the future since a considerable amount of cereals are consumed indirectly through meat.

Our goal was to produce Sankey diagrams for cereals at the scales of the Rhône-Alpes *région*, the Isère *département* and the SCOT[3] de Grenoble.

The informations we are looking for fall into 5 categories: primary production (1), intermediate consumption (2), stocks (3), trade (4), final consumption (5). For each of these categories, we found data sources (Agreste, FranceAgriMer, ProdCom and SitraM) that are however only available down to a given scale. To go below these scales we distributed the last available data among sub-territories using proxys. For example, we show the correlation at the *région* and *département* level between the CORINE Land Cover "non-irrigated arable land" category and the production of cereals **(1)**. Thus we use this correlation at the level of the SCOT where production data does not exist. **(2a)** The ProdCom database provides the country's production (usually in kg) of a large number of half products and finished products. Using conversion factors, it is possible to deduce the amount of primary material used by each industry. We distributed the national intermediate consumptions of these industries based on the number of employees in each region. We finally looked for the precise location of the factories to distribute the regional intermediate consumptions among sub-territories. **(2b)**

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[1]Statistical office of the French ministry of agriculture.

[2]Institut National de la Statistique et des Etudes Economiques.

[3]Schéma de cohérence territoriale : the SCoT is an urban-planning document dedicated to a group of towns or urban areas. By extension, we use the term SCOT to refer to the territory.

Regional consumption of cereals for livestock feed are not known, mainly because the cereals are distributed in various forms: self-consumption at the farm, grains bought by the farmer, or consumption of industrial compound products. We estimated the total livestock consumption of cereals for each region based on the data on livestock and slaughter and on the nutritional needs of the animals. Below the level of the *département*, we used the data from the Agreste Recensement 2000, although it is incomplete due to some confidential figures.

(3) Also because of the confidentiality of the data, information about the stock is partial. Averaging the figures throughout several years solves this issue since the variations of stock tend to compensate one year after another. In this work we therefore studied the period 2001-2009. **(4)** For the trade data, we used a revised version of the SitraM database[4] in order to avoid double counting between international and national trade.

(5) The per capita consumption was considered to be equal all over France. For instance, given that bread is mostly locally produced, we can deduce the amount of flour needed to sustain the final consumption of the territory. This is not true however for some other products, like glucose which is present in hundreds of derived products.

At the end, the more detailed the scale the more we need to use estimation technics. Moreover, we fill the data starting from the edges of the supply chain (production and final consumption), going to the center (intermediate transformation).

Our results for Rhône-Alpes and Isère seem globally consistent. There are however several incoherences which seem to point in the direction of imperfect trade data. At the scale of the SCOT de Grenoble, the smallest one studied here, it is interesting to visualize the separation between production and final consumption: the territory produces a lot of cereals but has no mill to convert them into flour. We therefore deduced it is imported. At any scale, self-sufficiancy is an interesting indicator to look at, even if this is not necessarily an objective for the territory. This concept can have a weak meaning (the territory produces more cereals than its inhabitants consume) or a strong meaning (the territory has access to the necessary production and transformation capacities to provide its inhabitants with every derived product).

We then developed a methodology to assess empirically the order of magnitude of the TRM survey[5]. This statistical survey about transport of goods by road is the main part of SitraM national data concerning cereals. In order to gain in reliability, we based the study on every French *région* and we aggregated the different kinds of cereals. We then calculated the regional final consumptions of flour, bread, biscuits, breakfast cereals, pasta and couscous (all together and expressed in their equivalent weight of grain) in two different ways. For the first calculation, we used production, transformation and trade data whereas we based the second calculation on the national per-capita average. The case of cereals is favorable because most of the trade concerns primary products: the inevitable uncertainties surrounding transformation factors do not play a big role. Assuming both results should be equal (same cereal diet all over France) and that the less robust data is the inter-regional trade by road, we made an estimation of the margin of error of the TRM data on cereals. Some *régions* are indeed a lot over or a lot under the expected consumption (with even a few negative consumptions). Depending on the *région*, an error of 20% and up to 210% in the TRM data would explain the results. This is however still to be confirmed by a theoretical study of the TRM survey. Whatever the conclusion, the SitraM database could still be utilized, as a minimum, to assess if a resource is rather local or non-local, or even how many kilometers it travels before arriving to its destination.

The methodology discussed in this article, although still perfectible, aims to be applicable to other sectors of the economy and to other territories without having to undertake time-consuming and expensive survey-based local studies. Applied mathematics and computer science could help improving the results in two ways. The first improvement could be provided by data mining, automatic search for correlations and inconsistencies in the data sources. The second help would be in the field of equation solving: reconstructing supply chains is like having to solve many sub-systems of equations (for each product: supply = use) that are linked together with some equalities (the transformation factors between primary and derived products). Applied mathematics could help to formulate and solve this problem in a more efficient and robust way than it is done currently.

Finally, once the flows in terms of quantities have been established, they can be translated into multiple environmental pressures such as the use of arable land, nitrogen, water or energy. We applied this with the example of the Water Footprint.

[4]Système d'Information sur le TRAnsport de Marchandises.

[5]Transport Routier de Marchandises.