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Measurement of the Supply of Agricultural Products: An International Comparison

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Recently the supply situation of agricultural products has received increased attention due to a growing world population, the rising demand for animal products, an increased use of biomass for bioenergy production, highly volatile market for agricultural and food products and climate change, among other things. Therefore, a proper method to represent the total agricultural production is required. With this in mind, this paper provides an international comparative survey of procedures that aggregate agricultural production. In order to identify international best practices with regard to accounting agricultural production, monetary and physical aggregations to measure food supply are analysed. Based on the international comparison, we identify the Austrian feed database and the French model "Foresight feed" as advanced methodological approaches.

INTRODUCTION

How many people can agriculture feed? The media have often discussed this question in recent years. Rising yield volatility and decreasing productivity growth, a growing world population, a higher worldwide demand for animal products as well as the increased bioenergy production are some of the reasons why the supply situation is of increasing interest [WBA, 2008; Mitchell, 2008; FAO, 2008; Qaim *et al*., 2009].

On closer inspection, the quantification of food supply is not easy to realize. First, agricultural products are heterogeneous and not directly comparable [Becker, 1988]. Second, livestock production plays an important role in food production with the consequence that in Germany, for example, about 60% of plant products are fed to farm animals [BMELV, 2009]. An accurate estimation of the extent and structure of forage needs of livestock production is therefore crucial for assessing the supply of the human population with agricultural products. As a consequence, feed balances are key elements when assessing the availability of supplies.

Agricultural accounts are used for quantifying food supply. These accounts are under pressure to adapt for several reasons. A particular challenge is the sharp increase in use of biomass for energy production which is currently not taken into account [Menrad *et al*., 2008]. Moreover, a purely quantitative assessment of the agricultural production will no longer meet the demands that are placed on multifunctional agriculture [Randall, 2002]. Finally, product and process qualities have become increasingly important [Theuvsen *et al*., 2007]. Knowing this, it is the aim of this paper to provide an international comparison of the state of development of various methods to aggregate agricultural production. This comparison provides an overview of a rarely tackled research topic, helps to identify communalities and differences between various approaches and, thus, best practices, and supports the verification of useful suggestions for further development of the agricultural accounts.

Although the calculation of the supply of food is the central goal of food balances, feed balances also have to be taken into account. Livestock production plays a major – and in some countries even dominant – role in agriculture. Since agricultural products can be used for food or feed, feed balances are a core element of each agricultural accounting system. Therefore, feed balances also have to be taken into account. In some countries, the agricultural accounting system even mainly focuses on feed balances due to their outstanding role for the availability of nutrients for human consumption.

The paper is mainly of interest for readers from the food and human nutrition area. Recent research has repeatedly highlighted the challenges of feeding a growing world population [FAO, 2009]. In this context, meat consumption has been identified as a key challenge to food security [Breustedt & Qaim, 2012; Foley *et al*., 2012; IFPRI, 2012]. Therefore, an overview over alternative methods for accounting agricultural products (including feed balances) is of growing relevance. The remainder of this paper is organized as follows: We will first introduce the concept of food and feed balances and then provide an overview of various systems of agricultural accounting currently used. The paper ends with a brief conclusion and an outlook. The paper is based on an in-depth scientific study on food and feed balances for the German

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Federal Office for Agriculture and Food. For more information see Klapp [2011] and Klapp & Theuvsen, [2011].

FOOD AND FEED BALANCES

Following the definition of Eurostat [2001] for the EU Member States, supply balances compare the amount produced and the utilisation of a product or a product group in a reference area (European Union/Member State) and a reference period (calendar and/or marketing year). Among other sources, supply balances are based on official agricultural statistics, crop reports and information provided by the food industry. Supply balances provide an overview of the production, import, consumption, and the evolution of stocks of agricultural products [BLE, 2006].

Supply balances which look only at one (unprocessed) product are to be distinguished from aggregated supply balances which take commodities and processed products into account. Technical conversion factors are used to convert processed products such as flour and pasta back into the underlying commodities, in this case grains. Such coefficients can also be used to calculate net quantities from gross quantities, such as the conversion of raw sugar into white sugar, cocoa beans into cocoa mass and crude fat into pure fat [Häfner, 1978; Ministère De l'Agriculture, de l'Agroalimentaire et de la Fôret, 2010; Eurostat, 2001]. With regard to emergency preparedness, domestic plant and animal production that could provide food during a crisis are quantified. In addition to the national supply balances, regional supply balances are prepared [BLE, 2006].

Feed and forage production are the link between crop and livestock production. Accordingly, feed balances in which fodder resources are compared with fodder use are essential to establish supply balances. Fodder resources represent the availability of suitable products for feeding, and they include both commercial feed and feed grown on-farm. Feed consumption is estimated considering the livestock population, the feed nutrient content and quality respectively, the demand elasticities as well as additional information from the feed industry [BMELV, 2009].

METHODOLOGY

The following overview is based on an extensive literature review. Since information on agricultural accounting systems is only rarely and incompletely published, supplementary expert interviews were conducted to get additional oral information or access to unpublished material. This was mainly the case with regard to the Eurostat [Mackova, 2008], the Danish [Olsen, 2008], the Austrian [Steinwidder & Krumberger, 2003], the French [CEREOPA, 2008], and the Swiss [Giulani, 2008] systems.

The description of the various systems which are or were in place mainly focuses on the following aspects:

- What is the aim or main focus of the system?
- Does the system include food or feed balances or both?
- Does the system provide a physical or a monetary aggregation of food or feed?
- Is the system still used?

INTERNATIONAL COMPARISON OF AGGREGATION SCALES IN AGRICULTURAL ACCOUNTING SYSTEMS

FAO

The FAO established supply balances for individual countries with the aim of quantifying the food security of the respective populations. According to the FAO definition [FAO, 2002] food security is given "if the entire population has physical, social and economic access to sufficient, safe and nutritious food at any time to meet daily food needs for an active and healthy life". The amount of information that is needed to create supply balances leads to very long product lists [FAO, 2001]. These lists are needed to determine the per capita consumption of energy, protein and fat. Based on these detailed data it is possible although not easy to obtain an overview on a country's degree of self-supply [FAO, 2008].

The FAO prepares overall balances to compare the production or the import of agricultural products with the total consumption [FAO, 2008]. Furthermore, the overall balances serve to calculate the overall degree of self-sufficiency and the dependence of a country on imports. In addition, the share of individual products in the total consumption can be determined with their help. The FAO distinguishes between aggregation in monetary units and in terms of nutrient content, but in the following only the physical aggregation with the aggregation scale "calorie" will be considered. The conversion factors of food with different calorie contents are derived from food composition tables; thus, the FAO publishes a list with the nutrient contents of 431 food products.

Formula 1. Calculation of the calorie factor:

$$\frac{(I)\ \text{kcal. consumption of commodities per day}}{(II)\ \text{item "food" in tons}} =$$

$$= \text{cal. factor (kcal. per day/ton)}\ (III)$$

To make the single product of each item of the supply balance addable, the per capita consumption of calories (I) of a corresponding product should be divided by the item food (II) of the product in weight. The result represents the amount of calories (III) in the chosen weight unit of the agricultural commodity which is finally available for human consumption. The information is given in kilocalories (kcal) per day and ton (see Formula 1).

The individual items in the supply balance for a product such as production, trade, feed, seed, processing, losses and food can be multiplied with this calorie-factor. The result is a consumption value in kcal per capita per day. This value allows an addition of all agricultural products under the various items of the supply balances [FAO, 2008].

Eurostat

Beginning in 1970, Eurostat made several attempts to create aggregated supply balances for all agricultural products and uniform feed balances for all EU Member States. The aggregated supply balances were derived from the German system. Eurostat made its final attempts in the early 1980s. Until then Eurostat published feed balances in which feedstuffs were expressed in product weight and feed units, which corresponded to the net energy of 1 kg of barley and were calculated according to Leroy's system [1954] of feed equivalents and in crude protein. For the feed balances Eurostat used a livestock unit (LU) that was calculated in 1977 from a data base established between 1970 and 1975. The reference animal of the LU-key is a dairy cow with an average annual milk yield of 3,000 kg. The LU-key does not precisely take into account the different performances of the animals and age groups. Although the definition of the LU-key corresponds to the definition used by the United Nations, Eurostat is going to use a more recent LU-key within the next few years [Fachmann *et al*., 2008; Mackova, 2008].

In 2002, Eurostat tried again to create a pan-European feed balance. The necessary data were provided by the EU member states according to weight on the basis of their national accounting systems. In addition, the member states were asked to describe the distribution of fodder between the major livestock species. The conversion of weights into metabolizable energy and digestible protein remained a task of Eurostat. Finally, Eurostat had to abandon the preparation of a pan-European feed balance due to a lack of data [Guia Lopez, 2008; Ribaille, 2002].

Denmark

Denmark generates supply balances for marketable products using the Eurostat approach in which feed is a residual. The crop yields, which for example are used for biogas production, are included into the position feed. The residual feed includes all quantities of products, which have not been collected separately and, additionally, the erroneous assessments of the remaining items in the supply balances, which distorts the calculated quantities of feed [Statistics Denmark, 2008a, 2008b; Olsen, 2008].

The feed supply is given in weight, Danish fodder units (DFE) and crude protein. The digestible protein content of feed was used until the year 2002/03. The crude protein and the DFE are used in statistics to make individual feeds comparable with each other. The last revision of the DFE took place in 2002/03 [Nehring, 1972; Lenkeit *et al*., 1969]. The DFE is a net energy value, which is based on 100 kg barley as a reference crop. Differences in feed evaluation systems for different livestock species are not taken into account by the DFE. Instead, it is simply assumed that all available feed is used by dairy cows, because milk production has the largest share in Danish cattle production. A differentiation in feed evaluation by accounting different DFEs for the individual production sectors, *e.g.* milk and pork, is not planned for the future [Statistics Denmark, 2008a; Olsen, 2008].

The DFE shows the total crop production in one value. In addition, products which are not available as fodder for livestock, but only for human consumption, such as potatoes, milling wheat and energy crops, are nonetheless included by Statistics Denmark according to their feed value. Since the entire crop production does not include specialty crops, ornamental horticulture products and crop residues, such as straw which remains in the field, Denmark estimates only a net base production [Statistics Denmark 2008b; StatBank Denmark, 2008].

The total feed consumption is also expressed in DFE, where the consumption of cereals is shown separately. Comparing the estimates of total crop production and total feed demand in DFE shows that the estimated production has, with some variation, not been sufficient to cover demand since the year 2001 [Statistics Denmark, 2008b].

Food production and consumption of all agricultural products are not calculated in Denmark [Olsen, 2008]. The DFE assesses plant products only and does not allow to calculate feed consumption in the production of individual animal products. Only some attempts have been made to develop a concept similar to the Natural Accounting System in Denmark.

Great Britain

In Great Britain (UK) an overall self-sufficiency rate is calculated as a measure of food security based on monetary aggregation of agricultural products. It is defined as the ratio of the output of primary agricultural production (value of raw materials) to the value of raw materials which serve as food. The food production is rectified for intermediate consumption. This approach prevents the overestimation of the ability of British agriculture to cover the food demands of the population. The restriction on the domestic agricultural production in the UK has a large impact on the identified self-sufficiency rate because agricultural production is largely dominated by imported agricultural inputs, such as feed, seed and cattle imports. Fertilizers, pesticides and fuel are defined as agricultural inputs [FCAG, 2006].

The total consumption of food results from the domestic production of food intended for human consumption, corrected by the import and export of local and foreign foods. Local foods are products which the local agriculture can produce in principle, for example pork or dairy products. In contrast, foreign foods are products which cannot be produced in UK for climatic reasons, such as tropical fruits. The consumption of local foods is consistent with the adjusted domestic production plus imports from foreign countries minus exports of domestic products. The differentiation of food consumption into overall food consumption and consumption of domestic products makes it possible to calculate the overall self-sufficiency rate as well as the self-sufficiency rate of domestic products [FCAG, 2006].

The imports and exports of food products are assessed by the Food Chain Analysis Group [FCAG, 2006] according to the agricultural commodities which are required for their production. Therefore imported and exported food products are divided into different categories: unprocessed, lightly processed and highly processed. A final distinction is made by taking into account the increase in value compared to the agricultural commodity, but not the extent of physical change. The conversion factors of processed products back into the agricultural raw products represent means of the added value of each processed product of the three categories. Duties, levies and export refunds have not been taken into account since 1998. Due to this change, food consumption and the degree of self-sufficiency increased by 16 to 17 percentage points.

Until the mid-1980s, an increase in the British degree of self-sufficiency was reported. The reason was price support due to the Common Agricultural Policy of the EU, which stimulated increasing food production. After a slight decline in the mid-1980s, self-sufficiency remained at a constantly high level until the mid-1990s. However, since 1995 the degree of self-sufficiency for all foods and for domestic foods decreased continuously, whether calculated by the old method which included duties, levies and export refunds, or with the new method. In 2006, the British self-sufficiency rate for local products was only 71.5% (58.1% for all products); [FCAG, 2006].

Austria

Austria has not implemented an aggregate standard for the representation of the supply of agricultural products. In the annual feed balance published by Statistics Austria [2007] each feedstuff is given in kg fresh weight and dry matter. The reported need for feed is the result of an estimate and not merely a residual as in Denmark. The information on feed resources and supply used by Statistics Austria are based on calculations by the Höhere Bundeslehr- und Forschungsanstalt Raumberg-Gumpenstein (HBLFA). The HBLFA has developed software which allows calculating the feed demand and the distribution of feedstuffs to individual livestock species for each year. The software includes a feed file that contains the nutrient contents of the concentrates. The quantity of roughage produced and its quality are estimated by HBLFA and Statistics Austria specialists each year. In order to do so, a network has been established to determine the annual Austrian roughage production quantitatively as well as qualitatively [BMLFUW, 2007; Steinwidder & Krimberger, 2003].

With regard to farm animals, it is assumed that a certain amount of feed is fed on the basis of fixed feed formulas. These standard formulas have to be adapted at least every 5 to 10 years. The remaining feedstuffs are distributed to the different livestock species until specific nutritional requirements are met. Feed allocation keys are used, which are based upon literature and consultant data, information from the feed industry and experiences about the distribution of the individual feed among different livestock species and categories. The allocation of feed starts with chickens, followed by pigs, horses, sheep and goats. The first priority is given to energy requirements, followed by protein requirements and, finally, requirements for dry matter intake. The last step is a comparison of nutrients and dry matter demand of cattle and the corresponding supply. For the distribution of feeds to ruminants, it should be noted that the percentage of concentrates is considered as given, because the basic feed which accounts for the largest proportion in ruminant feed intake, would displace the concentrates in the calculation at too high extents. The distribution of the concentrates to animal species and categories follows an optimal protein energy ratio [Gesellschaft für Ernährungsphysiologie der Haustiere, 1987; Steinwidder & Krimberger, 2003].

In the described procedure, an adjustment of the feed supply is necessary when feed availability falls below or exceeds the demand by at least 10%. In this case, the adjustment starts with the basic amount of feed and extends later to the traded feedstuffs. If a feed shortage in cattle exists, it is distributed proportionally among all animal species and categories. This is also true for a nutrient and feed oversupply [Steinwidder & Krimberger, 2003].

In the feed file of HBLFA the feed consumption of each species is given in dry matter, crude protein and feed energy. To compare the feed consumption of any animal, a species-specific energy evaluation system has to be selected [Steinwidder & Krimberger, 2003]. The proportion of dry matter demand of roughage consuming animals deviates greatly from the proportion of energy and protein demands. This means that the sole indication of the dry matter is not sufficient to make feedstuffs comparable, but that also the energy content is an important differentiator.

Following the distribution of feed over the different animal species and categories, the allocation of feed to the Austrian federal states occurs. The roughage feed is distributed to one-half according to the supply and the other half according to the animal population. The concentrates are distributed correspondingly to the swine and poultry populations, as well as the remaining demand (= total demand minus basic feed portion) of the roughage consumers [Steinwidder & Krimberger, 2003].

France

The French Service Central des Enquêtes et Études Statistiques (SCEES) produced from 1970 to 1985 feed balances for about 100 products which contained the feed in weight and feed units (for definition see Eurostat section). For the feed balances the SCEES considered compound feeds and agricultural primary products (excluding compound feed) separately and distributed them across individual species in accordance with their theoretical requirements according to Delage & Sauvant [1975]. This was an iterative process, so that SCEES distributed first the compound feeds and subsequently the concentrates according to the theoretically necessary demands for monogastric animals; the remainder of the feed supply was then allocated to ruminants [Casagrande, 2000].

With support from the Centre d'Étude et de Recherche sur l'Économie et l'Organisation des Productions Animales (CÉRÉOPA) the SCEES developed software that simulates the trade of compound feeds at the macroeconomic level. The software «Foresight feed», which is still used, optimizes the feed additive composition by taking into account the respective prices. The calculations are carried out annually and quarterly at the regional and national level. The model consists of several sub-models, which are based on data from France, Great Britain, Germany, Netherlands, Italy and Spain. Each sub-model represents a theoretical feed company in the middle of each country having a production volume equal to the total domestic production of feed in the respective country. Information which is necessary for the updating of the program is taken from national statistics and expert interviews. CÉRÉOPA [2008] publishes the estimates of compound feed production for one year in advance.

The model makes it possible to comprehend developments within the animal feed sector. The biggest benefit is the analysis of the competitiveness of individuals or groups of commodities. In addition to pure price effects, conclusions about the impact of changes in the quality of raw materials and of regulations to reduce pollution from animal production can also be drawn [Casagrande, 2000; CÉRÉOPA 2008].

In the early 1990s, SCEES with the support of the CÉRÉOPA attempted once again to create feed balance sheets which were only prepared for the years 1994/95 and 1995/96. In the current French statistics forage is only given in gross weight and dry matter; SCEES no longer estimates the distribution of feed to each animal species. SCEES is currently working on the development of new feed balances [Casagrande, 2000].

Switzerland

In Switzerland the Economic Accounts for Agriculture have emerged from the cooperation of the Federal Office of Statistics and the Swiss farmers' association [Schweizerischer Bauernverband, 2007]. The latter carried out calculations on food supply which were based on the calculations of the FAO. In addition, more extensive calculations are carried out, which summarize the products with an indication of product weight, digestible energy in Terajoules, protein, fat and carbohydrates in tons. Nutritional analyses of foods are from the food nutrition panels of Fachmann *et al*. [2008]. Overall degrees of food self-sufficiency of each basic nutrient are reported as the ratio of total consumption to domestic production. Based on product weights and by considering only the quantities available for human consumption, domestic production is expressed as a percentage of total consumption. Furthermore, the consumption of domestic products as a percentage of total consumption is calculated as degrees of self-sufficiency. However, no differentiation of the animal production based on the domestic forage production or on feed imports exists.

In addition, the Swiss farmers' association calculates the food consumption per capita. For that purpose they name the total food consumption in kg per capita per year and then the consumption per capita per year above the mentioned energy and the main nutrients, protein, fat and carbohydrates. Furthermore, the different food groups are given as percentages of total consumption.

The Swiss farmers' association publishes the energy and protein requirements of livestock in the Swiss feed balance. The energy requirement is specified in the species-specific energy evaluation step, the protein requirement is exclusively given in digestible protein. Parallel to the indication of feed demand, feed supply is calculated as a residual and given in digestible energy for ruminants as well as in a protein value which results from the evaluation of feed consumed about 83% by ruminants and about 17% by pigs [Schweizerischer Bauernverband, 2007].

There is a considerable difference of up to 30% between the calculated consumption of energy and protein and the residual feed. Thus, actual feed consumption cannot be derived directly from the calculations of the Swiss farmers' association. The Swiss feed balance must therefore be revised using calculations of the various animal categories. The calculations of demands of individual livestock categories are essentially based on the feeding recommendations of the Eidgenössische Forschungsanstalt für Nutztiere [1999a, 1999b]. A feed database complements these recommendations. The differences between the original and the revised calculations for a number of species can be as much as 25%. This demonstrates the significant need for revision of the Swiss feed balances [Eidgenössische Forschungsanstalt für Nutztiere, 1999a, 1999b; Giuliani, 2008].

In addition to the calculation of feed requirements, a distribution of agricultural feeding commodities to different livestock species is also available. The procedure is as follows: First, the distribution of raw material components in the mixed feed across the species is determined using information on compound feed sales for individual animal species. Then the plant products which are directly fed on-farm are distributed until the animals' residual demands for dry matter are met. Demand coverage of the animals is not fixed in an energy value, but the feed consumption and feed demands are given for each species in dry matter. The Swiss LU-key is used to verify the distribution by proofing the consistency of the percentage of each species in LU with the percentage consumption of each animal species [Giuliani, 2008].

United States

The United States started with the estimation of feed demand and total agricultural production parallel to the initiation of the estimation of agricultural production and consumption of food during and after World War II in Europe. In the US the supply of feed is a residual in the current feed balance. Although the cereal-processing industry in the United States would benefit from a national survey of feed consumption, the US government stopped the estimation of feed consumption in 1985. This was due to the more comprehensive knowledge about the nutritional requirements of the different livestock species and the development of new software for the calculation of feed rations. The consequence of these calculations based on new perceptions resulted in incorrect conclusions of the used feed rations [USDA, 1998].

Until now, animal indices indicating the minimum feed demand to cover animal performance are used to calculate the feed requirements of each species. They are based on rations obtained from accounting results and are supported by results from feeding experiments. The loss of roughage and concentrate feed from harvest until the intake by the animals is also taken into account. The calculation of feed requirements differentiates between the "grain consuming animal unit (GCAUs)", the "roughage consuming animal unit (RCAUs)", the "high-protein animal unit (HPAU)" and the "grain and roughage consuming animal unit (G&RCAU)". The different animal indices, which were revised the last time on the basis of data for the period from 1969 to 1971, use with slight variations dairy cows feed demands as a reference. The animal indices consider individual feed groups. The GCAU, for example, relates all animals according to their concentrates consumption, while the HPAU takes into account only the consumption of protein-rich feeds. Feed demand is measured in feed units (FU). An FU is equal to an American pound (= 453.59 grams) of corn, which consists of 78.6% of total digestible nutrients (TDN) [USDA, 1998].

In order to distribute the feed across the individual species, the percentage of each category of animal, which is expressed in the respective indices of animals, is multiplied

TABLE 1. Comparsion of agricultural accounting systems.

	Aim / focus	Physical or monetary aggregation	Focus on food or feed	System still in use
FAO	Quantifying food security	Physical and monetary	Food	Yes
Eurostat	Calculation of food supply and feed balances	Physical	Food and feed	No
Denmark	Calculation of supply balances of marketable products	Physical	Main focus: feed; additional focus: food	Yes
Great Britain	Calculation of self-sufficiency rate	Monetary	Food	Yes
Austria	Calculation of feed balance	Physical	Feed	Yes
France	Calculation of feed balance	Physical	Feed	Yes (but limited in scope)
Switzerland	Calculation of self-sufficiency rate	Physical	Main focus: food; additional focus: feed	Yes
United States	Calculation of food consumption and feed demand	Physical	Main focus: feed; additional focus: food	No

with the residual forage of each product to estimate the expected consumption of the respective feed for each species. Dividing this expected feed consumption by the number of animals produces the feed consumption per head. This tends to increase for all species, whereas the fodder consumption per animal product decreases over time because of more efficient feed conversion. The largest savings in feed supply per animal product are achieved in the milk production, because the proportion of high-energy feeds, which roughage consumers use efficiently, has increased the milk production per animal.

However, the use of animal indices has received criticism over the last two decades. This is due to the steadily increasing demand for feed of livestock, varying feed compositions caused by changing feed prices and varying prices for animal products. Furthermore, there is a fluctuating demand for feed for horses, mules and donkeys, which either are part of the domestic animals or – like race horses and pack animals – are part of the working animals. Although the estimation of feed consumption of these animal categories together is not very high, the feed consumption varies greatly depending on the work of the animals. The use of average rations would not reflect realistically the production processes in practice [USDA, 1998].

Table 1 summarizes the characteristics of the various systems described above.

CONCLUSIONS

There is a widespread interest in food security and the availability of agricultural products for food, feed and bioenergy production. The comparison of different national and supranational approaches to estimate total agricultural production and to prepare feed balances reveals that many different approaches exist simultaneously. The evaluation of plant products ranges from the declaration of the product weight in fresh mass and dry mass to the use of an energy value for animal nutrition. The comparability of plant products on the basis of fresh mass is low. The declarations of energy units for crop production come from national energy evaluation systems, which leads to results with limited comparability on an international scale.

The lack of comparability makes it very difficult to assess the data provided by each system and to compare results. Food and feed balances are a typical example of systems which clearly benefit from standardization. The literature on standard setting has identified the conditions under which private standard setting activities can be expected [Besen & Saloner, 1989]. These conditions are not met in the case of agricultural accounting systems. Therefore, standard setting in this area is a public good and requires government action which has only incompletely taken place over the last decades. Even basic concepts such as food security lack precise and undisputed definitions [FAO, 2002]. As a consequence, a variety of different systems have emerged and comparability of results has remained low.

For the statistical representation of products, Denmark has chosen the net energy evaluation for milk production. Switzerland evaluates plant products by the level of metabolizable energy for ruminants, while the United States operates with digestible energy. In most countries the feed value for ruminants as "smallest common denominator" is chosen in order to statistically evaluate the feed or plant products in the most simplified manner.

According to different studies, monetary aggregated self-sufficiency rates are more a measure of the competitiveness of agriculture and the food industry than the security of food supply. The explanatory power of the monetary aggregate is nevertheless regarded as sufficient, unless there are highly volatile prices for agricultural products. It is pointed out that the provision of calories is often much better than the relatively low self-sufficiency rates based on market prices indicate [FCAG, 2006; Holleran *et al*., 2007; McDiarmid & Holding, 2007]. The derivation of an overall self-sufficiency rate based on a monetary aggregation also produces a greater need for interpretation than one based on physical aggregation. All in all, a monetary aggregation is therefore less useful than alternative systems.

Physical aggregation comprises two fields of application. On the one hand, only the main nutrients of agricultural products are used as aggregation scales. The physical aggregation applied by the FAO and Switzerland serve only to calculate the coverage of the human needs for the particular nutrient. With this approach it is possible to represent the changes in nutritional habits, but the flow between plant production and animal production cannot be described. The material flows at the level of agriculture are not considered in the basic assessments of human nutrition. Keeping in mind the prevailing oversupply of nutrients for decades in the countries under consideration, the use of physical aggregation scales which are only focused on human nutrition must be rejected.

Most national feed balances calculate feed supply as a residual. In order to determine the amount of feed and to evaluate the use of single feedstuffs by different animal species some very interesting concepts are available. The use of various animal indices by the USDA seems in principle to be very useful because it accounts for the varying requirements of each species, although today's calculations are based on outdated data. A detailed breakdown of each feed is possible according to the species and the identification of the overall demand for energy, protein and dry matter is available in Steinwidder's & Krimberger's database [2003]. In this context, CÉRÉOPA's [2008] "Foresight feed" model deserves attention. The advantages of this model are the timeliness of the data and the ability to make predictions about the production of concentrates. However, a complex data management is needed. The Swiss farmers' association publishes the protein needs of livestock at the level of digestible protein. The energy requirement is given in the respective species-specific assessment of energy. The problem with the Swiss approach is the lack of comparability of the energy requirements of each species. In addition, the feed balance is subject to revision and the specification of a single energy scale is under discussion.

Overall, although no system is clearly the best, some interesting approaches could be identified. The Austrian feed database and the French "Foresight feed" model are particularly noteworthy here. However, before other countries could implement these systems, more in-depth analyses are needed whether the costs of these systems are worth the additional information gained. Then, too, the question how the increasing proportion of bioenergy production could be adequately addressed remains unclear. The dual use of maize for livestock feeding and bioenergy production, and the dual use of oilseeds, grains and sugar beets for human consumption and fuel production are important challenges which must be met. Without doubt, the question of whether an updated agricultural accounting system can be developed which adequately takes into account the information needs of decision makers, costs, and national accounting traditions requires further research.

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