

SECTION III

# Case studies

*This section presents a number of in-depth case studies of current approaches to assessing livestock feed situations and feed balances.*

*First, the global growth in demand for animal-source foods is assessed using state-of-the-art databases on global changes in human populations, diets and land uses.*

*This is followed by perhaps the most sophisticated example of a national feed assessment system – that which has been developed in Switzerland over decades. This case study provides an example of what can be accomplished with highly developed national agricultural databases.*

*The case study from India provides insights into one country's approach to assessing livestock feeds in an extremely diverse set of livestock production systems involving high degrees of utilization of crop by-products.*

*The subsequent four case studies address spatially extensive livestock production systems in rangelands and grasslands of Africa and Asia. In contrast to the intensive systems in Switzerland and India, these systems make heavy use of remote-sensing data.*

*The Livestock Early Warning System (LEWS) that has been applied in the Gobi region of Mongolia goes even further in using models driven by climate and other biophysical data to assess risks of feed shortages in the near future.*

*This is followed by a chapter on estimating livestock feed balances, in which animal nutritional requirements are considered in more detail in relation to feed quality as well as quantity.*

*A chapter on the use of ecosystem simulation modelling to assess spatially extensive livestock systems integrates many of the approaches taken in previous examples while considering system dynamics and the effects of herbivory on vegetation and soils.*

*The concluding chapter reviews state-of-the art methodology for assessing feed situations in grasslands and rangelands.*

# 7. Demand growth for animal-source foods: implications for livestock feed production

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## 7.1 INTRODUCTION

Each year, the Food and Agriculture Organization of the United Nations (FAO) produces its flagship publication: *The State of Food Insecurity in the World* (most recently, FAO, 2010a; FAO, 2011a). While the topical emphasis varies from year to year, the central theme is about how many people in the world are under-nourished. This number is re-evaluated each year using a food balance sheet (FBS) approach.

For a broad group of crop and livestock commodities, national estimates of the food available for human consumption are made, along with the caloric content of each commodity. These data are used to calculate total availability of calories in the country. Given that different age and sex groups have different minimum caloric requirements, data on population structure are used to estimate the total caloric requirements for the entire population. Household survey data, typically used to measure poverty, are used to estimate the country-specific distribution of calories. Then, from the total calories available, total calories needed for a given population and the distribution of calories, the number of people who fall below the minimum energy requirement is estimated. This represents the number of undernourished people.

A summary is provided below of how estimates are made of the food available for human consumption, both now and in the future. Two separate aspects of this analysis are then described, both of which point to the importance of accurate measurement and monitoring of livestock feed production: first, in the estimation of the supply and demand for the feed-crops themselves; and second, in the estimation of demand for livestock commodities and how this is expected to grow.

## 7.2 SUPPLY AND DEMAND FOR AGRICULTURAL COMMODITIES, NOW AND IN THE FUTURE

The approach taken to estimating the amount of food available for human consumption uses a Supply Utilization Account (SUA)<sup>5</sup> framework, structured as follows:

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<sup>5</sup> Supply utilization accounts are time series data dealing with statistics on supply (production, imports and stock changes) and utilization (exports, seed, feed, waste, industrial use, food, and other use) which are kept physically together to allow the matching of food production with food available for human consumption.

Demand (total domestic use)  
 = food available for human consumption + industrial non-food uses + used as feed  
 + used as seed + waste (+ discrepancy)  
 = production + (imports - exports) + (opening stocks - closing stocks)

A base year is selected, in which, for each commodity and country, production, demand and net trade balances are estimated. For the base year, SUAs are driven by production estimates. Net trade, feed, seed, waste and industrial use are estimated and the food available for direct human consumption is the residual. A major component of data preparation work is unravelling the SUA element production for the base year into its constituent components. The rather complex procedure is described in detail in Alexandratos (1995) but, very simply, crop production requires estimation of areas, cropping intensity and yields, and livestock production requires estimation of total stock, off-take rates and carcass weights (or yields per animal in the case of milk and eggs).

Crop production = area planted × cropping intensity × yield

Meat production = number of animals × off-take rate × carcass weight

Milk and egg production = number of animals × yield per animal

To make predictions about the future, food available for direct human consumption is projected in per capita terms using the base year data, a set of estimated food demand functions (Engel curves<sup>6</sup>) for each commodity in each country, and assumptions about the growth of per capita Gross Domestic Product (GDP). Estimates of economic performance are extended from the World Bank's *Global Economic Prospects 2006* (World Bank, 2006), which provides per capita GDP projections up to 2015 (Alexandratos *et al.*, 2006). The total projected food demand is then obtained by multiplying the projected per capita levels with projected population figures, taken from the medium variant *World Population Prospects 2002* revision (UN, 2003), which projects the world population to grow from the 2000 level of 6.07 billion to 8.13 billion in 2030 and 8.92 billion in 2050.

### 7.3 THE IMPORTANCE OF ACCURATE ASSESSMENTS OF FEED FOR CROP COMMODITIES

It was mentioned above that, in the base year, the food available for direct human consumption is estimated as the residual, having accounted for net trade, and subtracted the quantity of each commodity use for feed, seed, waste and industrial use from its estimated production. It is clear, therefore, that the more precise the estimate of each crop commodity that is destined to produce livestock feed, the more accurate will be the estimate of the food available for human consumption. To give some indication of how important the estimation of feed is, Table 7.1 provides some of the SUA data for some crops which make major contributions to feed resources in India.

Of the crops grown in India in 2000, pulses made the largest absolute contribution to feed production. However, this pattern is projected to change dramatically in the future. Projections suggest that by 2030 the production of feed will be dominated by maize: 70 percent of that grown will be used for feed. Other cereal crops, such as wheat, are also projected to become much more important for the production of feed. Because the estimation

<sup>6</sup> An Engel curve describes how household expenditure on a particular good or service varies with household income.

TABLE 7.1

**Production, estimated feed use and percentage used as feed for selected crops in India**

	2000			2030			2050		
	Prod	Feed	Prop	Prod	Feed	Prop	Prod	Feed	Prop
Pulses	13 020	1 125	8.6	14 616	1 600	10.9	14 413	2 000	13.9
Wheat	72 446	869	1.2	114 000	4 000	3.5	135 000	11 000	8.1
Raw sugar	34 092	829	2.4	56 289	1 200	2.1	68 140	1 800	2.6
Paddy rice	135 282	541	0.4	168 000	3 000	1.8	177 000	6 000	3.4
Maize	12 285	210	1.7	24 739	17 500	70.7	34 000	24 500	72.1
Millet	10 067	161	1.6	6 749	500	7.4	4 666	1 200	25.7
Barley	1 472	133	9.0	1 522	50	3.3	1 638	50	3.1
Sorghum	8 003	96	1.2	6 014	400	6.7	4 799	600	12.5
Veg. oil & oilseed	7 456	66	0.9	12 915	162	1.3	17 107	233	1.4

Note:

Prod = Production in thousands of tonnes

Feed = Estimated feed use in thousands of tonnes

Prop = Proportion in percentage

Source: data based on Alexandratos *et al.* (2006).

of the amount of food available for human consumption is heavily dependent on knowing how much of the overall production of these important staples will be used for feed, it is clear that measuring and monitoring feed production is critical for accurate assessment of the numbers of under-nourished people.

## 7.4 DEMAND GROWTH FOR ANIMAL-SOURCE FOODS

Driven by urbanization, population growth and increasing wealth, the demand for animal-source foods in developing countries is growing rapidly (FAO, 2010b). Livestock is one of the fastest-growing sectors in agriculture, presenting potential opportunities for economic growth and poverty reduction in rural areas. But positive social outcomes of livestock sector growth may not be ubiquitous and, in some areas, there may be detrimental social effects as small-holders dependent on livestock for their livelihoods are squeezed out from the sector by competition from larger players who can benefit from economies of scale. Beyond possible social problems are environmental, and animal and public health issues that are likely to be associated with rapid, poorly regulated livestock sector growth. Understanding where growth in demand for livestock commodities is likely to occur, and where production will rise to meet this increasing demand, are therefore important for a number of reasons. One question relates to livestock feed: Where will the additional feed resources come from?

FAO's most recent predictions on the supply and use of agricultural commodities extend previous projections from 2015/2030 (Bruinsma, 2003) to 2030/2050 (Alexandratos *et al.*, 2006). These new estimates have been used by Robinson and Pozzi (2011) to map changing demand for livestock products, and the associated changes in production that will be

required to meet that growth in demand. The approach taken is to map consumption of livestock commodities based on the distributions of rural and urban populations in the base year and at chosen dates in the future. For the base year (2000), the Global Rural Urban Mapping Project (GRUMP) population map was used (CIESIN *et al.*, 2004) but was adjusted so that total number of people in each country matched those used by the FAO projections (based on UN, 2003). For the 2030 and 2050 projections, the adjusted GRUMP 2000 maps were used, and the base year population figures were multiplied by a 'growth' factor, so that the total number of people in each country matched FAO's projected figures. Urban and rural population totals for 2000, 2030 and 2050 were also estimated, based on the proportions of population living in urban areas from the United Nations' *World Urbanization Prospects* (UN, 2008). Then, for each country, the urban and rural population distributions from GRUMP were adjusted to match the UN/FAO urban and rural totals in 2000, and 'grown' separately to map future urban and rural populations.

For each time period, the national food consumption for each commodity was distributed equally among the population of each country and expressed as consumption per square kilometre. Absolute changes in consumption were then estimated for each commodity by subtracting the map of consumption estimates for the base year (2000) from those for 2030 or 2050. Table 7.2 shows changes in consumption from 2000 to 2030 for each commodity for the developing regions of the world. The results reflect changes

TABLE 7.2  
Growth in demand for livestock products from 2000 to 2030

Region	Beef		Milk		Mutton		Pork		Poultry		Eggs	
	Abs	Prop	Abs	Prop	Abs	Prop	Abs	Prop	Abs	Prop	Abs	Prop
East Asia and Pacific	8 798	130	23 765	132	1 669	58	28 075	63	22 522	143	10 188	45
<i>China</i>	<i>6 888</i>	<i>132</i>	<i>15 936</i>	<i>143</i>	<i>1 537</i>	<i>56</i>	<i>22 050</i>	<i>54</i>	<i>14 609</i>	<i>121</i>	<i>6 810</i>	<i>34</i>
Eastern Europe and Central Asia	290	11	4 364	15	204	40	112	5	2 310	108	684	28
Latin America and Caribbean	7 302	58	39 818	72	239	54	4 405	100	14 434	126	3 246	78
Middle East and North Africa	1 929	112	17 913	111	1 287	103	9	52	6 296	243	1 799	148
South Asia	3 367	84	118 942	126	1 722	115	950	160	11 491	725	5 947	294
<i>India</i>	<i>1 338</i>	<i>51</i>	<i>79 330</i>	<i>119</i>	<i>588</i>	<i>85</i>	<i>921</i>	<i>160</i>	<i>8 865</i>	<i>844</i>	<i>4 251</i>	<i>280</i>
Sub-Saharan Africa	3 768	113	20 939	107	1 883	137	1 106	155	3 235	170	1 727	155
All Regions	25 454	81	225 741	97	7 004	88	34 656	66	60 287	170	23 590	70
High-Income Countries	2 441	15	31 312	31	275	33	2 935	22	12 414	65	1 911	24

Notes:

'Abs' is the absolute increase in annual consumption from 2000 to 2030 in thousands of tonnes; 'Prop' is the increase expressed as a percentage of consumption in 2000.

The regions are defined according to the World Bank 2010 classification (World Bank, 2010).

Source: Adapted from Robinson and Pozzi (2011)

both in population and in consumption patterns. The most striking factor is that growth in poultry consumption outstrips growth in all other animal-source foods in all regions of the world. By far the most dramatic change is the projected increase in demand for poultry meat in South Asia: a 725 percent increase overall. This is driven by growth in demand in India where a staggering 850 percent increase is projected over the 30-year period.

A closer look at projected growth in demand for poultry meat in India shows that the consumption of poultry meat is due to increase by 8 865 400 tonnes from 2000 to 2030. This raises important questions: Where will this additional meat come from? How will it be produced? And what resources will be required to produce it? The FAO projections do not anticipate this increase in demand to be met through imports, but through an increase in production. Furthermore, since the growth in demand will arise largely through increasing wealth and urbanization (Robinson and Pozzi, 2011), it is reasonable to assume that most of it will have to be met by a rapid intensification of the poultry sector. This in turn begs the questions: How much additional feed will that require? And how much land might be required to produce that?

A rough calculation of the feed requirements for this can be made as follows, under the broad assumption that chicken accounts for the vast majority of poultry meat in India. Based on a dressing percentage of 75 percent, and a feed conversion ratio (FCR) of 2.3 it was estimated that 27 187 227 tonnes ( $[8\ 865\ 400 \div 0.75] \times 2.3$ ) of additional feed would be required per year by 2030 compared with 2000.

The composition of broiler feed in India varies somewhat seasonally and with the price of ingredients; typical values are provided in Table 7.3, compiled from information provided in USDA (2004). Given the required weight of each ingredient, and their expected yields (year 2000 estimates from the FAO projections), the additional cropped area needed to provide each of those ingredients can then be estimated (Table 7.3).

This results in an estimated total additional cropped area of some 23.6 million hectares; a land area approaching that of the United Kingdom (24.2 million hectares<sup>7</sup>). In reality, however, some of the projected increase in poultry meat consumption will be met through backyard, scavenging systems that do not require any additional land. It is also likely that, as demand grows, crops grown specifically for feed will be partially replaced

TABLE 7.3

**Feed composition for broiler chickens in India; crop production coefficients for the ingredients (see text for explanation and data sources) and estimates of production and cultivated area required to meet additional broiler chicken feed demand**

Ingredient	Proportion (%)	Weight (tonnes)	Yield (tonnes/ha)	Area (ha)
Maize	55	14 952 975	1.8216	8 208 704
Rice	10	2 718 723	2.8507	953 704
Soybean	30	8 156 168	0.8222	9 919 932
Oilseed	5	1 359 361	0.2997	4 535 740
Total	100	27 187 227		23 618 079

Source: Robinson *et al.* (2012).

<sup>7</sup> [www.listofcountriesoftheworld.com](http://www.listofcountriesoftheworld.com).

with by-products of the food industry. Other considerations are that feed or components thereof may be imported, and there will certainly be intensification in the production of the feed crops themselves. The 2000 estimates of corn yields used here are 1.81 tonnes per hectare, which is very low by most standards: 3.2 tonnes per hectare in Thailand, 4.4 China and 8 in the United States, for example (USDA, 2004). There is clearly much scope for intensification of corn production but, in semi-arid India, significant increases in yield would require irrigation, posing further questions: Where will the water come from? What will be the effects of increased rainwater harvesting in terms both of local environmental functions and broader-scale effects on water resource availability?

While representing the upper limit of increased land requirements for feed production to meet production targets for demand growth, this type of analysis shows that the required increases in the amount of land and water that will be needed to meet the growing demand for animal-source foods in the burgeoning cities of some parts of the world are likely to be immense. The land use changes required to meet these demands may considerably undermine ecosystems services not only locally, where these feed resources are produced, but on a global scale.

In this context, it would appear essential that global feed resources, particularly those destined to supply the rapidly growing, intensive production systems of the developing world, are carefully evaluated and monitored in order that appropriate policies are developed and implemented to ensure sustainable growth of the livestock sector. As management consultant Peter Drucker famously once said: "If you can't measure it, you can't manage it." Assessment of available feed resources will generate information on *how much* and *when* different feed resources are available, which will enable optimal policy and management decisions to be taken regarding the use of these resources. In addition, this information will enhance efficiency and profitability of the animal feed industry and assist researchers to formulate sustainable feeding strategies. Such efforts will, in turn, translate into enhanced food security. Furthermore, coping with emergency situations such as drought and floods will be facilitated by better information on the availability of feed resources. Spatial and temporal assessments of current and forecasted feed resources, including forages, will assist in disaster management and policy-making. Information on the availability and use of feed resources could also be used better to determine input-output relations as has been done for estimation of edible protein output to protein input for various countries (Table 7.7 in FAO, 2011b). Results such as these could be made much more accurate if proper feed inventory systems are in place. The estimation of feed resources could also improve the accuracy of estimates of the environmental impacts of livestock, not only through land use transformations, as discussed above, but also in the estimation of greenhouse gas emissions associated with livestock production.



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## 8. The Swiss feed balance

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### 8.1 INTRODUCTION

#### 8.1.1 History

In Switzerland, the Statistics Division of the Swiss Farmers' Union ("Schweizerisches Bauernsekretariat") made efforts to prepare a feed inventory in 1911–1913. But annual inventories have been conducted on a regular basis only since 1933. In the years after 1933, the inventory comprised three sections: the first specified energy needs and protein needs in starch units and digestible protein; the second determined the supply of domestic feedstuffs; and the third determined supply of imported feedstuffs. The feed inventory continued in this form until the 1970s.

A fundamental revision took place in the 1980s with the establishment of a national food plan for times of crisis. Revised time series were calculated back until 1976. Starch units were replaced by metabolizable energy for ruminants, and energy needs were calculated by form (net energy of lactation, net energy of growth, etc.) for each livestock category.

The last revision was carried out in 2008 and 2009, leading to the current method for the Swiss Feed Balance, which is presented here.

#### 8.1.2 Purpose of the feed balance

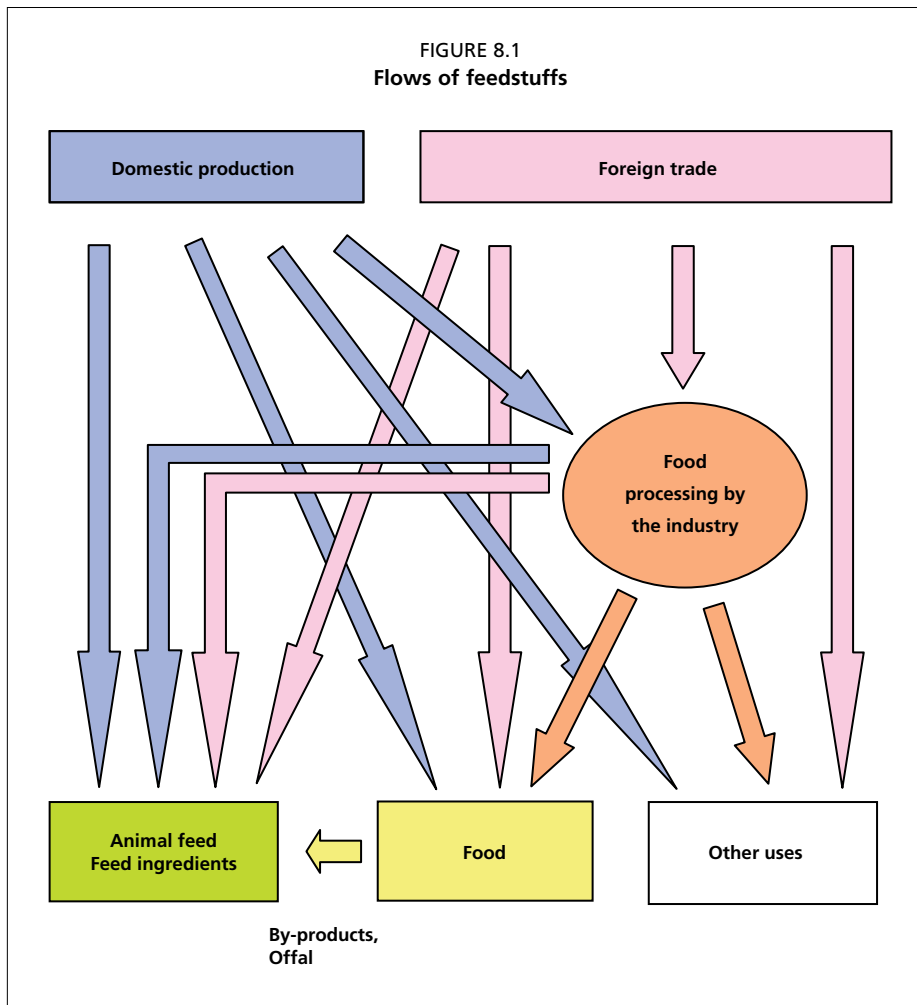
The early use of feed inventories must be viewed against the background of World Wars I and II. Switzerland was twice encircled by belligerent countries and the supply of food was often difficult. Consequently, it was essential to make an inventory of available food resources and production systems in order to optimize agricultural production. During the Cold War, this aspect of provision remained important. Even now, it has kept its importance in the framework of the "National Economic Supply" (National Economic Supply, 2011), a governmental structure for the management of supply crises. Today, different scenarios of crisis leading to feed and/or food deficiency can be imagined: severe droughts leading to poor harvests and low water levels in the Rhine River that restrict importations of bulk freight (e.g. cereals, fuel) on the waterway from the North Sea, accidents in nuclear power plants or terrorist attacks and war-like events with great impact. The revisions in the 1980s continued to be based upon these considerations.

In the meantime, many new applications have been found for the feed balance, especially in relation to emerging environmental issues: production of greenhouse gases, nutrient balances and flows of biomasses. The Swiss Feed Balance also produces relevant data to assess the economic importance of feed production for animals within the national accounting system of the Federal Office of Statistics (Swiss Statistics, 2011). However, the

securing of the feed and food supply has kept its place and with regard to the 2007/2008 food crisis even won some new importance. As a conclusion, the feed balance still provides important, basic information to policy-makers.

## 8.2 METHODOLOGY

The basic aim of the Swiss Food Balance is to evaluate the feed available for farm animals in Switzerland, i.e. the supply. Everything that can be eaten by livestock animals is included as feedstuffs. In practice, the list of feedstuffs is limited mostly by hygienic reasons. In Switzerland, feedstuffs come from different sources. The greatest part is cultivated and harvested for this purpose (mostly forage and feed grain). Still, livestock use a multitude of products, most of which are by-products and offal from food processing. Some of these products serve as raw materials for the feed industry. The feed balance considers the feeding components before transformation and mixing through the feed industry. Figure 8.1 shows the flows of feedstuffs.



The feed balance calculates the feedstuffs which are available for livestock animals during one calendar year from 1 January to 31 December. In addition, the needs of the livestock animals are calculated on the basis of the results of a livestock census and compared with the available offer of feedstuffs. This serves as a quality check. Important differences between the results of the two statistics have to be checked for possible errors or inaccuracies. The formula for the calculation of available feedstuffs is the same for every product:

$$\begin{aligned} \text{Available feedstuffs} = & \text{Domestic production} - \text{Change of domestic stocks} + \\ & \text{Imported feedstuffs} - \text{Exported feedstuffs} - \text{Imported pet food} - \text{Change of} \\ & \text{imported stocks} + \text{By-products from imported raw materials} \end{aligned}$$

The feed balance has a fixed framework (products, categories of livestock animals, feeding values), which is only changed during revisions, and a variable component (quantities, proportions for the distribution of the feedstuffs between animal categories), which is adapted to yearly changes. The product list and the hierarchical structure of the feed list has been established on the base of the *Handbook for compiling supply balance sheets – animal feed: supply* (EUROSTAT, 2002). The nomenclature has been expanded according to Swiss conditions. The feeds are grouped as follows:

Marketable feedstuffs:

- Feedstuffs of vegetable origin (e.g. barley)
- By-products of processing (e.g. sugar beet pulp)

Normally non-marketable feedstuffs:

- Feeding stuffs of animal origin
- Annual fodder (e.g. fodder beet)
- Perennial fodder crops (e.g. grass silage)
- Crop by-products (e.g. sugar beet leaves and tops)
- Other (e.g. offal)

The available quantity of each product is distributed among the different livestock categories, which are the same as those described in the EUROSTAT manual:

- Cattle (with cows as sub-group)
- Sheep and goats
- Pigs
- Poultry
- Other: equines, rabbits, deer (fallow or red deer)

For each product, the distribution key according to livestock categories has to be defined. First, forage (fresh grass, hay, grass silage) is distributed among forage-consuming animals. Products which are used completely for a certain livestock category are assigned. After that, other products are distributed according to information from the feed industry. At this point, a first check takes place: the quantities are compared with the needs for each livestock category. If necessary, the distribution is corrected. As soon as the quantities fit, the quantity of energy and protein distributed to each category is also compared with the needs. This check is not easy to interpret because the quality of forages can widely vary from one year to another.

The various feedstuffs have very different properties. An aggregation can only be made if a common denominator can be found. The most important measurement unit is therefore dry matter. Additionally, gross energy and crude protein are considered. Appropriate feeding values are used for each livestock category:

**Cattle, sheep and goats**

- Metabolizable energy for ruminants
- Net energy of lactation
- Net energy of growth
- Absorbable protein in the intestine

**Pigs**

- Digestible energy for pigs
- Crude protein

**Poultry**

- N-corrected metabolizable energy for poultry
- Crude protein

**Other**

- Digestible energy for horses
- Digestible protein for horses

The publications of the Swiss Agroscope Liebefeld-Posieux research station have been used as the source for feeding values. The feeding values are only changed within revisions. The values are registered in a database and linked to the different products on the feedstuff list.

The annual data of the feed balance are compiled in a database. Foreign trade data are directly imported from the corresponding database. Other data have to be entered manually. An existing project that has developed a food balance database could also serve as a source for the by-products of food processing. In the meanwhile, those data must also be entered manually.

### 8.3 SOURCES FOR ANNUAL DATA

Foreign trade data (importation, exportation, pet food) come from the Swiss Federal Customs Administration. All products which are imported for feeding purposes and thus declared are considered. Exported feedstuffs and pet food have to be discounted from the resulting importations. The product list of the customs administration is more elaborate than the product list of the feed balance. Therefore, one product of the feed balance can match with multiple products of the foreign trade list.

Information for domestic production has several sources:

- The indications for feeds of vegetable origins come from production statistics (pulses), from the enterprise balance (potatoes, cereals) or estimations from SFU Statistics (oil seeds, processed forage).
- By-products of food processing: information from the industry or estimations from SFU Statistics. The milling industry has its own statistics for Switzerland which cover by-products. By-products of the brewing industry are estimated on the basis of the beer production as indicated by the brewing industry. The amount of sugar produced by the sugar manufacturing units provides information about the production of sugar beet pulp. The quantities of pomace (apples, pears) are surveyed by the Federal Office for Agriculture. The by-products of oil production are estimated on the basis of production and appropriate rates of yield.

- Feedstuffs of animal origin are almost completely prohibited in Switzerland. The quantity of milk products used for livestock is estimated on the basis of milk production statistics elaborated by SFU Statistics together with the milk sector.
- Quantities of fodder beets are taken from production statistics and those of green and silage maize from forage statistic (SFU Statistics).
- Quantities of perennial fodder come from forage statistics (SFU Statistics).
- Crop by-products (mostly stems and leaves of sugar beets) are estimated on the basis of production statistics.
- Other feedstuffs (vegetables, fruits, offal) are estimated by SFU Statistics.
- Fodder maize and grassland forage production are estimated by SFU Statistics.

By-products from the food processing of imported raw materials are calculated using the same methods as used for calculating by-products derived from domestic raw materials (e.g. from vegetable crops, as above).

The final component is the change of stocks of domestic and imported feedstuffs. There is no systematic survey and SFU Statistics uses only the data of Réserve Suisse, the responsible organization. For domestic products, only the stocks of cereals, pulses and oil cakes are entered. For imported products, stocks of rice (broken), oil seeds and by-products of starch production are also entered.

It is not always easy to separate pet food from the feedstuffs for livestock. This is especially true for domestic production because no data are available. However, those quantities should not be very significant.

## 8.4 FORAGE (ROUGHAGE) CALCULATION

Forage calculation is based on production statistics for fodder maize and grass (fresh, hay, silage, artificially dried) produced annually by SFU Statistics. The following terms are used for forage production:

- Gross yield = surface biomass
- Yield in the field = harvested yield – field losses
- Net yield = yield in the field – losses due to conservation

The terms for utilization of forage are:

- Consumption of forage = net yield fed to livestock in the reported year
- Ingestion of forage = consumption of forage – feeding losses (wastage)
- Forage needs = quantity of forage necessary for covering maintenance, growth, production and gestation of livestock animals

The following is the set of parameters that is used for estimating forage production (production approach):

- Altitude of the areas used for forage production and the corresponding production potential
- Area used for forage production based on area data of SFU Statistics
- Estimated yields based on surveys of SFU Statistics
- Dry matter content and quality of forage plants
- Meteorological conditions

Production is estimated for the calendar year according to the type of area as follows:

$$\text{Production} = \text{area} \times \text{annual yield/area unit}$$

Areas are classified according to the official production zones: plains, hills, mountains I-IV. The areas and the production zones come from SFU Statistics. The average yields are estimated from standard yields that are reported by SFU Statistics. The standard yields are then corrected for meteorological conditions, as determined in part from data collected in regular surveys. The estimated production of fresh matter is converted to dry matter.

In parallel, the quantity of forage is also estimated on the base of utilization (utilization approach). The corresponding factors of influence are:

- Duration of green fodder period
- Utilization of forage
- Dry matter intake of livestock animals
- Duration of pasture season in mountain regions (alps)
- Capacity for forage stocks (hay, silage)
- Losses in the field through conservation, during feeding

The utilization approach estimates forage consumption in a calendar year. This approach calculates consumption according to the type of forage. Maize is subdivided into green maize and maize silage. Grass is grouped according to utilization or conservation type: alpine pastures, other pastures, fresh grass (fed in the barn), artificially dried grass, hay (first and following cuts) and grass silage. Some of those products are further subdivided according to quality.

While the production approach covers only domestic production, the utilization approach also considers imported forage. The difference between the production and utilization approaches results in the quantity which must be imported or covered by stocks. For a period of several years, there has to be a balance between production and utilization, which takes the following form:

$$\begin{aligned} \text{Forage balance of the actual year} &= \text{yield in the field} - \text{losses from conservation} + \text{excess of forage of} \\ &\text{the preceding year} - \text{shortage of forage of the preceding year} + \text{excess of imported forage (almost} \\ &\text{no forage is exported)} - \text{forage consumption by livestock animals} \end{aligned}$$

The result is often positive in good years and mostly negative in bad years is. A balance of inputs versus outputs should be obtained over a period of several years. Because the same grassland can be exploited several times a year, the assignment of conservation type is somewhat arbitrary and is controlled by calculated needs.

## 8.5 ESTIMATION OF NEEDS

“Estimated needs” is the check value on the estimated available quantity of feedstuffs. It incorporates effects of quantity and the quality of forage. It is especially useful in that it distributes available quantities according to livestock categories (Table 8.1).

The needs of the livestock animals are calculated according to the feeding recommendations of the research station Agroscope Liebefeld-Posieux. Some of those recommendations are taken from the “Wirzkalender” (Agridea, 2011), a handbook for farmers. For every livestock category the needs for dry matter, energy and protein are estimated. Energy and protein needs are calculated in the appropriate unit for each livestock category.

There is no single measurement unit that can be used for every livestock category. Units (number of animals, fattening days and so on) are particular to each kind of animal.

TABLE 8.1  
Measurement units for the estimation of the needs according to livestock categories

Livestock category	Livestock unit	Energy unit	Protein unit
Cattle, maintenance and breeding	Number of cows and bulls	Net energy of lactation	Absorbable protein in the intestine
Cattle, gestation	Number of cows	Net energy of lactation	Absorbable protein in the intestine
Cattle, milk production	Tonnes of fat corrected milk	Net energy of lactation	Absorbable protein in the intestine
Cattle on alpine pastures	Days of alpine pasture	Net energy of lactation	Absorbable protein in the intestine
Fattening calves	Days of fattening	Metabolizable energy	Digestible protein
Other cattle	Days of fattening/growth	Net energy of growth/lactation	Absorbable protein in the intestine
Sheep, breeding animals	Number of breeding animals	Net energy of lactation	Absorbable protein in the intestine
Sheep for fattening	Days of fattening	Net energy of growth	Absorbable protein in the intestine
Goats, breeding animals	Number of breeding animals	Net energy of lactation	Absorbable protein in the intestine
Goats for fattening	Days of fattening	Net energy of lactation	Absorbable protein in the intestine
Pigs, breeding animals	Number of breeding animals	Digestible energy	Crude protein
Pigs for fattening	Number of fattening animals	Digestible energy	Crude protein
Poultry	Tonnes of feedstuffs	Metabolizable energy	Crude protein
Equines	Number of animals	Digestible energy	Digestible protein
Rabbits	Tonnes of feedstuffs	Digestible energy	Crude protein
Other ruminants	Number of animals	Net energy of growth	Absorbable protein in the intestine

As already noted above, the delimitation of pet food is sometimes difficult. Official livestock statistics exclude the animals of pet owners and livestock owners with few animals and little cultivated area. Generally, pet animals are not imported but they have some weight in the categories of rabbits and equines.

## 8.6 CALCULATION AND PUBLICATION

SFU Statistics calculates the annual feed balance once a year. The provisional feed balance for year  $t$  is calculated at the end of year  $t + 1$ . If necessary, the feed balance for year  $t - 1$  is revised.

The results of the feed balance are published every year in *Statistical censuses and estimations in agriculture and nutrition* (USP, 2009). The results are presented in three tables:

- Table 1: Product list with the results of several years and quantities of fresh matter, dry matter, gross energy and crude protein.



- Table 2: Product list with the origin of the feedstuffs and quantities of fresh matter, dry matter, gross energy and crude protein for one year.
- Table 3: Utilization of the feedstuffs for several years according to livestock categories with dry matter and appropriate feeding values for each livestock category.

Estimated needs are no longer published. They serve exclusively as check values and as an aid in the process.

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# 9. The Indian feed inventory

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## 9.1 INTRODUCTION

### 9.1.1 Rationale

Numerous studies have shown that shortages of feed resources have been major constraints in improving livestock productivity in India. In spite of this, feed resource assessments have received little attention, which is evident from the fact that no public or private sector agency produces national or regional information on feed resources. Updated information on availabilities and requirements is important not only for short- and long-term planning but also for ensuring national food security. Over the years, there has been a continuous debate on the livestock feed situation in India and some researchers have made attempts to quantify animal feed resource availabilities and requirements (Sen and Ray, 1941; Mudgal and Pradhan, 1988; Sampath *et al.*, 2005). All studies conducted so far have consistently shown that requirements exceed availabilities, and it is likely that the gap will further widen in the future. But these projections of deficits have to be viewed with a certain degree of circumspection and reservation. This is especially true given that milk, egg and meat productivities in India have consistently increased over the last two decades. These increases could not have been solely due to increases in livestock numbers; improvements in overall feed availability have no doubt also been important. It is against this background that the National Institute of Animal Nutrition and Physiology in Bangalore undertook a systematic study to assess the availabilities and requirements for feed resources in different states of India.

A feed inventory of a particular area/region will provide information on the type of feed resources available and their quantities, which can then be compared with available livestock numbers to arrive at the status of the area/region in terms of whether feed availability is sufficient, in surplus or in deficit. This kind of information can be of enormous assistance for policy-makers, concerned government departments, NGOs and development agencies in formulating and implementing meaningful livestock development activities and tackling natural calamities such as drought and floods. For example, improving livestock production by improving the germplasm of animals and by improving veterinary care is only possible when there are adequate feed resources. This can only be known by carrying out assessments of feed resources. Such assessments can also help livestock traders, feed companies and commerce ministries in making informed decisions with respect to the nature and quantities of commodities, the feed resources that could be traded locally, potential areas for feed markets, and the nature and the quantities of feed resources involved in imports and exports.

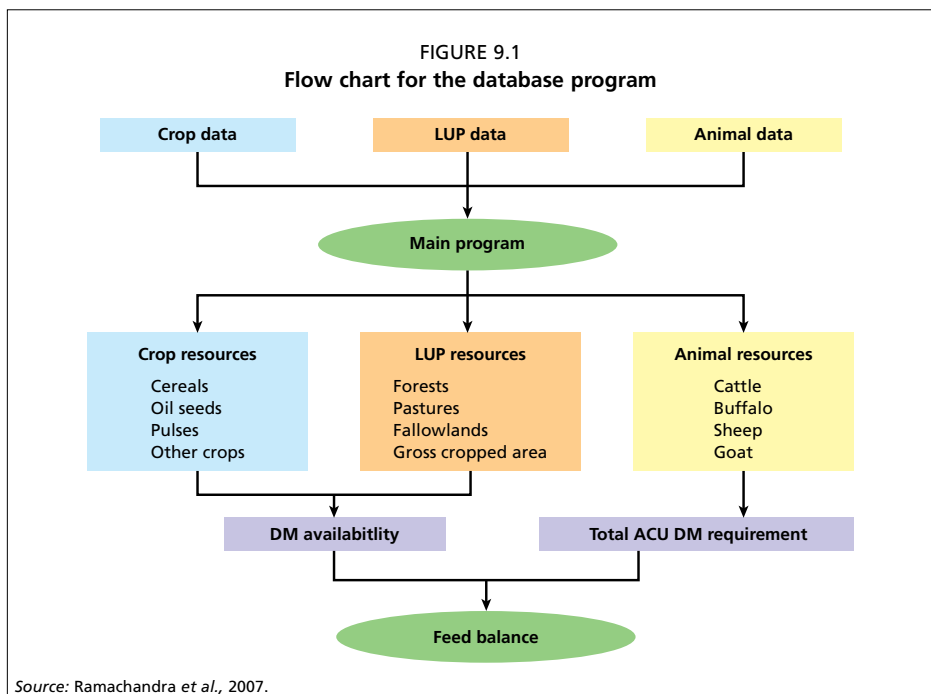
## 9.2 METHODOLOGY

### 9.2.1 Inputs

There are basically three major inputs required for assessing feed resources and feed balance: i) feed resources from crop data; ii) green fodder from land classification data; and iii) feed requirement from livestock censuses.

To arrive at the availability of feed resources from crops, it is necessary to know the harvest indices and extraction rates of different products and by-products from crop production data. The harvest index is the ratio of tonnes of utilizable crop by-product to tonnes of primary crop harvested, for example tonnes of wheat straw per tonne of wheat grain. The extraction rate is the fraction of harvested primary crops used for feed, for example the tonnes of wheat grain used for feed to total tonnes harvested. Similarly, the average production potential of cultivated fodder, extent of land under fodder, average biomass production potential of other land categories must be known to arrive at total green availability. For those categories where information is lacking, efforts are made to consult with subject matter specialists and fill the gap by recording the true values. For assessing feed requirements, data is required from a livestock census that gives a detailed breakdown in terms of age groups and production functions (milk, meat, draught).

Generally, crop production and land utilization pattern data are published annually while the livestock census is carried out periodically. In India, the census takes place every five years and the annual figures can be arrived by simple calculations based on the latest census figures and the compounded annual growth rate for each category of livestock. The crop production data, land utilization data and livestock census data for a particular region for the same period must be matched to arrive at the status of feed resources availability. The structure of the program that integrates and processes the input data is show in Figure 9.1.



### Input 1 – Crop production data

Using the worksheet in Table 9.1, different feed resources – straws (crop residues), grains, bran, husk and oilcake (concentrate) – can be calculated from the production data of different crops. As an example, for every 100 tonnes of wheat grains produced, 100 tonnes of wheat straw would be produced (100 multiplied by the harvest index of 1.0), the proportion of wheat grains used for feeding would be 2 tonnes (100 multiplied by the extraction rate of 0.02) and wheat bran availability would be 8 tonnes (100 multiplied by 0.08). Similarly the availability of groundnut haulms and groundnut cake for every tonne of groundnut would be 2 tonnes of haulms (1 multiplied by 2.0) and 0.7 tonnes of groundnut cake (1 multiplied by 0.70). The dry matter content of all the above feed resources is considered as 90 percent except for sugarcane tops which are high in moisture and where it is assumed that the dry matter content would be 25 percent.

TABLE 9.1  
Harvest indices\* and extraction rates used in the calculation of feed resources from crop production data in India

Crop production	Harvest index		Extraction Rate	
	Crop residues	Oilcakes	Grains	Bran/husk
Paddy	1.3	-	0.02	0.08
Wheat	1.0	-	0.02	0.08
Sorghum	2.5	-	0.05	-
Pearl millet	2.5	-	0.05	-
Barley	1.3	-	0.10	-
Maize	2.5	-	0.10	-
Finger millet	2.0	-	0.05	-
Small millets	2.5	-	0.10	-
Other cereals	2.0	-	0.10	-
Total Pulses	1.7	-	-	0.03
Groundnut	2.0	0.70	-	-
<i>Sesamum indicum</i> seeds	-	0.70	-	-
Rape & mustard	-	0.70	-	-
Linseed	-	0.70	-	-
Niger	-	0.70	-	-
Sunflower	-	0.70	-	-
Safflower	-	0.70	-	-
Soybean	-	0.70	-	-
Sugarcane	0.25	-	-	-
Coconut	-	0.0625	-	-
Cotton	-	0.0499	-	-

\* Harvest index is the ratio of tonnes of utilizable crop by-product to tonnes of primary crop harvested.

Source: Ramachandra et al., 2007.

### **Input 2 – Land utilization pattern**

For assessing green fodder availability, the following factors which represent the average biomass production potential per unit hectare are extracted from the land classification data. Land utilization pattern data has the following categories – gross cropped area, forest area, permanent pastures, cultivable waste lands, current fallows, other fallows and area under miscellaneous tree crops from which green fodder is available for feeding livestock.

In the case of areas under fodder cultivation, it is assumed that 4 percent of the gross cropped area is under fodder cultivation and the average fodder yield would be 40 tonnes/hectare/year. Thus, multiplying 4 percent of the gross cropped area by 40 tonnes (0.04 X 40) gives 1.6 tonnes/ha/year. In the case of forests, because it is assumed that only 50 percent of the forests are available for fodder production and the average fodder yield is around 3 tonnes/ha/year, the factor of 1.5 tonnes/ha/year is used (0.5 X 3). For the remaining categories, the calculation is straightforward and the different factors are presented in Table 9.2. The green yield is on a fresh basis and average dry matter content of green fodder is assumed to be 25 percent.

### **Input 3 – Livestock census**

For calculating feed requirement, detailed livestock census data are required, including estimates of age class distributions. A rough estimate of the quantitative adequacy is the first step and this can be done by assessing the requirements in terms of dry matter. Dry matter requirements of ruminants (cattle, buffalo, sheep and goats), equines and camels are calculated on the basis of a standard adult cattle unit (ACU) of 350 kg body weight, utilizing the conversion factors for species and age class (Table 9.3). Assuming that a minimum dry matter intake of 2 percent of body weight would be sufficient, an ACU would require 7 kg (350 X 0.02) of dry matter per day. Accordingly, the total dry matter requirement can be calculated by converting the livestock numbers into ACUs. The feed balance can be derived by combining total potential feed availability with total requirements.

**TABLE 9.2**  
**Green fodder yields for land use classifications**

<b>Land use category</b>	<b>Green fodder (tonnes/ha/year)</b>
Gross cropped area	1.6
Forests	1.5
Permanent pastures	5.0
Cultivable waste lands	1.0
Current fallows	1.0
Other fallows	1.0
Miscellaneous tree crops	1.0

Source: Ramachandra et al., 2007.

TABLE 9.3  
Conversion factors for calculating adult cattle units (ACUs)

Species	Category	Conversion factor
Buffalo	>2.5 years	1.14
	1.0–2.5 years	0.50
	<1.0 year	0.17
Cattle	>2.5 years	1.00
	1.0–2.5 years	0.34
	<1.0 year	0.11
Sheep/goat	>1.0 year	0.10
	<1.0 year	0.03
Equines	>3.0 year	0.57
	<3.0 year	0.33
Camels	>4.0 year	1.00
	<4.0 year	0.57

Source: Ramachandra *et al.*, 2007.

## 9.2.2 Data integration

Once the data on crop production, harvest indices for various feed resources, land utilization pattern and average biomass production potential of different land categories are available, it is possible to calculate the total potential feed availability in a region. Similarly the feed resource requirements for all livestock in a region can be calculated based upon the detailed species and age-specific census data. For each species and age class, nutrient requirements are calculated in terms of dry matter, protein and energy requirement for a given population. From the protein and energy requirements for different categories of livestock, the feed resources requirements in terms of green fodder, crop residues and concentrates can be deduced in relation to the prevailing feed practices. Feed availability and requirements are calculated using a program developed in Microsoft Access or Excel.

The complete stepwise approach for establishing a regional feed inventory is as follows:

1. Obtain the necessary data on total crop production for the region from the concerned department or from agricultural statistics; usually the information is published annually in the form of reports either in hardcopy or posted on the respective department web sites.
2. From the crop production data, list all the crops and their by-products that are used for feeding livestock.
3. Prepare a list for harvest indices and extraction rates, which are proportions of crop and crop by-products used for livestock feeding; for some resources, the information may be missing and for those products the factors can be determined with the help of the experts from the concerned crop or processing sector.

4. Because the feed resources originating from crops constitute the major feed resources, the list of crops and their extraction rates should be as exhaustive as possible to account for all resources (as shown in Table 9.1).
5. Potential available feed resources can be deduced from crop production data using harvest index and extraction rates.
6. Generally the dry matter content of crops and crop-based products is around 90 percent and the same value can be used to determine total dry matter availability.
7. Additional information in terms of import/export of resources and alternate uses of resources if available should be accounted for to improve the precision of assessment.
8. The proportion of cropped area used for fodder cultivation and the average production of fodder should be known in order to estimate green fodder production.
9. For green fodder production from categories other than cultivated fodders, the land utilization pattern should be known; the area of land under different categories must be multiplied by the average production potential of green fodder to establish total green production (as shown in Table 9.2).
10. The dry matter content of green varies and average dry matter content is assumed to be 25 percent to establish total available dry matter.
11. Adding the total feed resources from crops and greens gives the total potential feed availability in a region.
12. The requirements of feed for ruminants, equines and camels can be assessed by converting the different species and categories of animals into adult cattle units based on ACU conversion factors as indicated in Table 9.3.
13. Total annual feed requirements can be calculated from the total ACU by multiplying the total ACU by 365 (number of days in year) and 7 (assuming 2 percent dry matter intake [DMI] for an ACU weighing 350 kg body weight).
14. Comparing the total feed availability with the requirement gives the status in terms of sufficiency, deficiency or surplus for that particular region.
15. A region can be classified based on the dry matter availability and generally a dry matter availability of less than 2 percent can be considered as deficit, dry matter availability between 2 and 3 percent can be considered as adequate, and above 3 percent can be considered as surplus.

The above approach is a simplified version in which only the quantitative feed-adequacy is determined for ruminants, equines and camels. The requirements of other species of livestock such as poultry, pigs, etc. can be added to total requirements and the feed balance can be derived. The approach provides a framework which can be expanded to include more details for assessing the quantitative feed adequacy for all species of livestock.

Assessing the quantitative and qualitative feed requirements precisely requires detailed information with regard to the census (age and function classes [in milk, dry, draught, breeding, etc.]) and the nutrient requirements for age and function classes, average productivities, average body weights, etc. After assessing the total nutrient requirements in terms of dry matter, protein and energy, the nutrient content of the available feed resources and prevailing feeding practices must be factored in to arrive at the feed balance. Some

basic knowledge of animal nutrition with regards to the nutrient requirements of livestock and nutrient profile of feed resources is essential for carrying out this exercise, or alternatively, animal nutritionists can provide the data necessary to calculate the precise feed balance.

### 9.3 UPDATING THE INVENTORY

The tasks associated with maintaining and updating the inventory include updating changes associated with crop production, land utilization pattern and the livestock census. While the data on crop production and land utilization pattern changes are available annually, the livestock census is carried out at periodic intervals and the annual figures can be calculated using the latest census data and the compounded annual growth rate. Further addition of newer feed resources (if any), changes in extraction rates of any of the by-products due to changes in processing, and changes in export/imports must be accounted for. A large number of agro-based by-products and species of livestock like aquaculture and pet animals have been left out in the assessment and these need to be included. Further, assessment and refinement is a continuous process and the information needs to be updated and refined as new information becomes available.

Finally, the precision of assessment can be judged by relating the total livestock numbers and livestock produce with total feed resources availability. This is based on the fact that if a particular number of livestock and quantity of livestock produce has been achieved, the feed resources for the maintenance requirements of that livestock and livestock produce must be accounted for. The closer the requirements for maintaining and producing livestock produce and availability in terms of total feed resources, the better is the accuracy. A large gap between availabilities and requirements indicates that there is scope for improving the assessment.

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