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The Land Use and Biomass Flows of the Argentinean Agri-food System

A model-based analysis for 2003

Thesis for the Degree of Master of Science in Industrial Ecology

GUILLERMO JOSÉ GARRIDO

Department of Energy and Environment
Division of Physical Resource Theory
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Abstract

Global demand of biomass, such as food, feed, bio-energy, and fiber for wood and paper, will increase considerably in the near future. Initiatives are needed to assess the best options to meet internal and external demands of biomass-based services and to set plans for future sustainability in Argentina.

The food and agriculture system is by far the largest anthropogenic activity in terms of appropriation of land and biological primary production in the country. Therefore, this study intends to contribute to a better understanding of land and biomass requirements for food production. More specifically, the aim of this study is to quantify the land use and biomass flows, in energy and mass terms, of the Argentinean current agri-food system.

The method used in this study is based on Material Flows Analysis (MFA) in which linkages between sources, pathways, and material's fates (or sinks) are estimated, with due regard to the law of matter conservation. For biomass data structuring and linkage, the ALBIO model was used.

Some of the main results show that 1) while the total primary energy production in the country during the year 2003 was 3.6 EJ, the total gross energy appropriated as phytomass by the agri-food system was 8.6 EJ and 5.2 EJ for total production and internal consumption respectively, 2) of the total phytomass appropriated, 50% stays on the field where sown, 30% ends up as livestock respiratory heat, methane and manure, 13% is exported as different biomass commodities, and only 1.5% ends up as food eaten 3) while animal food represents 29% of an average Argentinean diet in energy terms, the energy induced to produce animal food constitute 90% of the total phytomass appropriated, 4) animal food presents the lowest overall efficiency at 0.8%, while processed and non-converted vegetables commodities present the best with an overall efficiency of 17%, 5) phytomass appropriated by beef cattle is more than 74% of total, 6) permanent pasture, non-agricultural land and cropland pasture dominate the feed intake of the animal system with 70% of the total animal feed intake, 7) by-products used by animal sub-systems constitute only 5% of marginal phytomass appropriation, and 8) the difference between internal consumption and total production is only 40% in terms of land and phytomass appropriation.

After analyzing results, questions arise such as, how can we boost the agri-food system efficiency? Where should be focused efforts to increase efficiencies? How much can we increase animal food production efficiencies? Shall we modify our diet habits? How can we reduce food waste? To analyze and discuss food production, international trade and eating habits, inter-disciplinary studies and inter-institutional interaction in the agri-food system are necessary.

Acknowledgements

First of all I would like to thank my supervisor, Stefan Wirsenius, for giving me the opportunity to apply the ALBIO model to the Argentinean case. His time dedicated to guiding me through the study and methodology process and his valuable comments and suggestions that were crucial to improve the study.

I also want to thank the FAO, and especially José Benites, the FAO representative in Argentina, for giving me the opportunity to carry out the study within the institution, and offering the necessary support and institution facilities.

This thesis could not have been written without the invaluable information supplied by workers, researches and teachers from the agriculture and food system, cited all trough this study. To all of them my special thanks.

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Last but not least, I would like to warmly thank the Garrido family and Agustín Lewitt, who were crucial to motivating me during this study.

Contents

1. Introduction

In this section we intend to guide the reader through the context in which this study is done, its significance for the analyzed country, and the objective and specific scopes of the study.

1.1 Background

It is well known that in the near future, global demand for services of biomass, such as food, feed, fiber for wood and paper, and bio-energy, will increase considerably. Population growth, continuing increase in purchasing power, and policies aimed at mitigating climate change will all contribute to an increasing demand for biomass. As a consequence, increasing areas of land will have to be used for the production of more food, fiber and energy crops. This will lead to increased competition for land and biomass energy production, since most of the required land will have to come either from land freed from its current use in food and fiber production in agriculture and forestry, or from exploitation of unused areas of productive land.

The Argentinean situation is similar to that at the global level, and there is already concern there about forthcoming land competition. The link between the energy sector and agricultural sector may become important due to scarcity of land. Therefore, improved knowledge of options for keeping down the long term land requirements and the associated effects on this country is essential. In addition, since Argentina is an important producer of biomass-based services, it needs to analyze the long term demand and supply of biomass for food, energy and biomaterials.

The country needs to undertake a range of initiatives aimed at assessing the best options for meeting internal and external demands of biomass-based services, and to set a plan for future sustainability. These initiatives can be varied in their focus, due to the diversity and the large number of sustainability issues of the sector. A complete strategy needs to take into account a range of policy issues and agronomical, ecological, technological, economical and social factors.

Farmers, food processing industry, traders and citizens see production, conversion and consumption, from different and often isolated perspectives. Therefore it is necessary a holistic approach of sustainable food production, consumption and trade, to avoid isolated and contradictory solutions. The national and local governments have agreed in promoting sustainable development to consolidate policies of growth with equity. The agri-food system is relevant in terms of economic, environmental and social impact within the country. And therefore, it is crucial the agri-food system is in line with the sustainable development principles.

Within the country many sustainability studies of the agri-food system have been performed, such as Viglizzo et *al.* (1991, 1995, 2001, 2002, and 2004). This particular study has been performed only globally by Wirsenius (2000, 2003), but has not been done locally. Similar studies to this one, related to country surveys level are the material, energy and monetary flows analysis in the Swiss food sector (Faist et *al.*, 2001), and the Finish MFA model to asses economic and environmental consequences of food production and consumption (Risku-Norja and Mäenpää, 2006).

To that extend, the present study is an attempt to contribute to a system perspective understanding of the agri-food system in Argentina. Its physical description and analysis is a fundamental starting point toward overall sustainable development guidelines.

1.2 An Industrial Ecology perspective

Nature's metabolism works in cyclical flows; that is, a tree which grows in the forest takes nutrients from its environment to grow up, but when it dies its nutrients go back to the environment to be re-used by a coming or growing plant. In this way the loop of nutrients can work for very long periods of time. This is not the way how society is using resources nowadays. Resources are used as linear flows and are lost at the end of their exploitation. Shouldn't society function as nature if we expect to be sustainable in the long run? The Argentinean agri-food system needs to be prioritized and studied deeply with this perspective if we intend to be more sustainable every day.

If analyzed in a local context we may sometimes be sustainable and environmental friendly when doing certain activities within the agri-food system, but how do we know if we are contributing and going in the direction of whole system sustainability? The Industrial Ecology (IE)[1] field has developed methods to consider and study phenomenon in that way. It applies existing tools and newly developed ones for dealing with increasingly complex environmental issues. Although in Argentina some studies have looked at this topic, a deeper global comprehension of the agri-food system is necessary.

Therefore, this kind of analysis of materials and energy flows in a life cycle perspective, across multiple disciplines, and with the objective of finding possible improvements and solutions for the system as a whole, is an ideal starting point.

[1] White (1994) defined IE as the study of the flows of materials and energy in industrial and consumer activities, of the effects of these flows on the environment, and on the influences of economic, political, regulatory, and social factors on the flow, use, and transformation of resources.

1.3 Purpose and nature of the study

The purpose of this study is to analyze the Argentinean agri-food system in an Industrial Ecology perspective, to contribute to discussions which integrate diets, food production, and phytomass appropriation[2].

The method used in this study was based on Material Flows Analysis (MFA)[3], in which linkages between sources, pathways, and material's fates (or sinks) are estimated, always keeping in mind the law of conservation of matter.

The ALBIO model, developed by Wirsenius (2000), which is a comprehensive model for mapping the turnover of the biomass in the agri-food system, was used in this study[4].

1.4 Objectives of the study

This study intends to contribute to an overall comprehension of biomass-based services in Argentina. More specifically, the aim of this study is to quantify land use and biomass flows, in energy and mass terms, of the agri-food system. By doing so, the following issues will be addressed:

I. *What is the total terrestrial phytomass appropriation for the purpose of human food?*
II. *What is the relative importance of different biomass categories with respect to the total phytomass appropriation?*
III. *Which influence has trade on Argentina's phytomass appropriation? What would the picture look like if no international commerce existed?*
IV. *How much of the appropriated phytomass ends up as eaten food?*
V. *What are the efficiencies of the system?*
VI. *What is the relation between food intake and phytomass appropriation?*
VII. *How large are the differences in efficiencies between individual food commodities?*
VIII. *What are the differences of phytomass appropriation for different animal sub-systems?*
IX. *What is the relation between food intake, feed use, and phytomass appropriation of animal food commodities?*
X. *Which difference does internal use of by-products, such as crop residues, make to lessen the demand of biomass production?*
XI. *What is the amount of manure generated by animal sub-systems?*
XII. *What is the amount of methane generated by animal sub-systems?*
XIII. *What is the amount of by-products and residues generated?*
XIV. *Where do residues from the agri-food system end up?*

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[2] The study does not cover other types of energy use (anthropogenic energy inputs) or a wider range of environmental and socioeconomic externalities that result within the food system.
[3] MFA is a systematic quantitative assessment of the physical flows and stocks of materials within a system defined in space and time. It connects the sources, the pathways, and the intermediate and final sinks of a material [Paul Brunner and Helmut Rechberger, 2004].
[4] When studying the food system with an IE perspective; it is necessary to use an interdisciplinary perspective, bringing together mathematics, statistics, agronomic, food and human nutrition fields.

2. Description of the applied model

In this section a brief description of the most important features of the ALBIO model structure is presented. For a detailed explanation of how the model is structured, the reader is referred to Wirsenius (2000).

The applied model is based on a mass-energy balance analysis of the flows of biomass in the food and agriculture system, from production on cropland and permanent pasture to intake as food. All processes are depicted on a mass and energy balance basis. The description of each process complies with balance of total dry matter (DM), as-is weight (i.e. including water), and gross energy (GE). It includes all major types of phytomass being used in the agri-food system. Besides the edible-type crops, various types of animal forage crops and pastures are included. It contains detailed and explicit descriptions of productivity, feed energy requirements and feed dry matter use for major animals. It also contains physically descriptions of the generation and the subsequent handling of all major by-products and residues.

The up-stream boundary is above-ground phytomass production. The down-stream boundary for biomass eaten by animals and humans, down-stream boundaries are respiratory heat and gases, and feces and urine. The products which are related to the food chain but are not produced as main products or are not produced on land, such as fish and cotton crops flows, are described by the model as “system-external related flows”.

2.1. Variables and parameters

In this sub-section, we describe briefly the model depiction of the “production of animal food commodities” and “converted vegetable food commodities”. For a description of “production of Phytomass”, “distribution, trade and storage”, and “assignment and use of internal by-products and residues” the reader is referred to Wirsenius (2000, pp. 13-54).

2.1.1. Production of converted vegetable food

With required supply of vegetable food products, the model calculates the required distribution of phytomass products for use as feedstock.

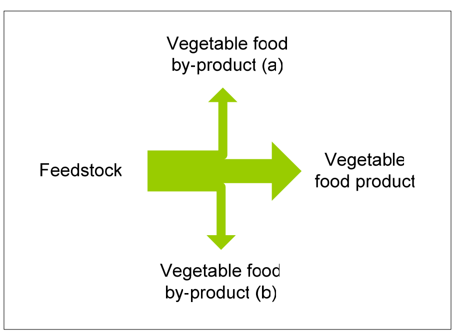

Figure 1. Conversion of feedstock.

As shown in Figure 1 the model calculates the necessary phytomass input products (cereal grains, oil grains, etc) extracted or refined to obtain a specific converted vegetable food commodity (oil, sugar, flour, etc).

2.1.2. Production of animal food commodities

The model depicts the conversion of phytomass to animal food commodities. To understand how pools and flows are estimated, see Wirsenius (2000, pp. 26-27). Figure 2 shows typical flows in a pool of an animal sub-system.

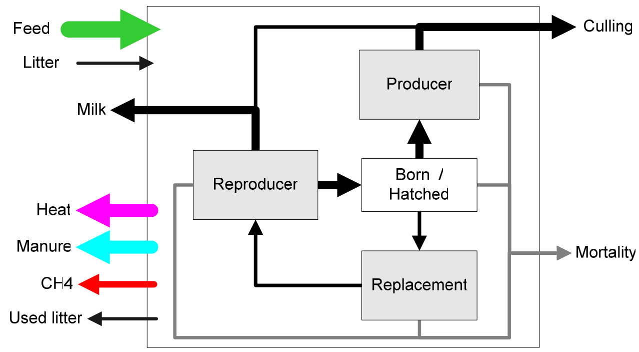

Figure 2. Animal sub-systems flows

Feed dry matter intake

As Wirsenius (2000, p. 28) explains, feed DM intake is a function of the energy requirements and the energy density of the eaten feed mix. For each animal category, the feed use of this balancing flow is automatically adjusted so the energy content of the feed matter intake complies with the calculated feed energy requirement of the animal category.

Energy requirement		Energy density		Dry matter requirement
NE [MJ/day]	/	ED [MJ/kg DM]	=	DM [kg/day]

For all categories in both cattle sub-systems, the balance post is “permanent pasture”. For the pig sub-system, “forage-vegetable” is used as balancing post. For both chicken sub-systems, the balancing post are “cereal grains”.

Biomass processed included

Relevant livestock-related processes included in the model are a) Cooking of soybean seeds and sweet potato tubers. b) Hay and silage production from fresh grass-legume. c) Silage production from whole-cereals (maize and sorghum). d) Meat and bone meal production from carcass fifth quarter. e) Fish meal production from fish.

Feed energy Requirement

Feed energy requirements are calculated with equations predicting requirements of energy and other nutrients (see [Wirsenius 2000, sections

2.3.2 to 2.3.6]) as proposed by the Committee on animal Nutrition at the US National Research Council (NRC tables)[5] for cattle milk, beef cattle, sheep, and goats. [Whittemore, 1993] is used for predicting requirements for pig, and [Larbier and Leclercq, 1994] for those for egg and meat-type chicken. Energy requirements for cattle, sheep and goats are calculated in net energy (NE), unlike for pigs and poultry it is in metabolizable energy (ME). Equations are divided by different types of energy requirements, that is, maintenance, gestation and lactation (or Egg Production), and growth.

In Figure 3 and Figure 4, is shown how the GE intake by different animal sub-systems flows in the model. Together with the specifications of the pools and flows, the calculations give the feed energy requirement per number of animal-in-stock in the sub-system. This estimation combined with the total meat-type production, give the feed energy requirements per amount of meat-type generated.

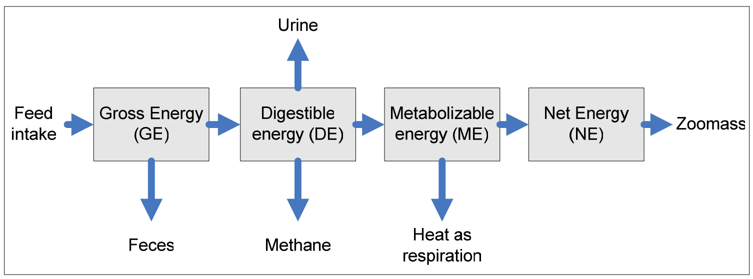

Figure 3. Cattle, Goat, Sheep and Pig energy intake flows.

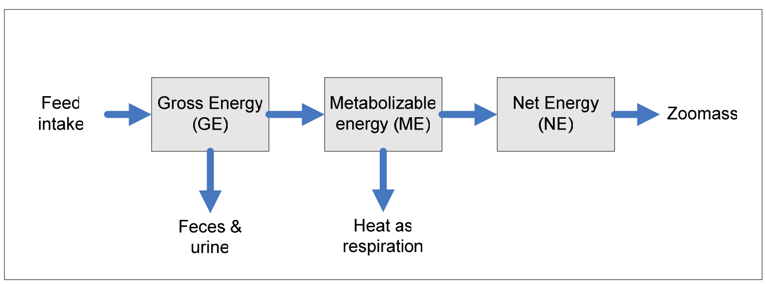

Figure 4. Egg chicken and meat-type chicken energy intake flows.

Feed options and feed energy densities

The energy content of feedstuffs for ruminants is specified in terms of GE, DE, ME, NE_l NE_m, and NE_g[6]. Cattle milk equations are taken from the NRC tables of feed composition (1989), beef cattle carcass from the NRC tables of feed composition (1996), sheep carcass from the NRC tables of feed composition (1985), and goats carcass from tables of feed composition (1981). The energy content of feedstuffs for pigs and poultry is specified in terms of GE, DE, ME. Pig equations are taken from the NRC tables of feed composition (1988), and poultry from the NRC tables of feed composition (1994).

[5] For cattle milk is taken from NRC (1989), for beef cattle from NRC (1984), for sheep from NRC (1985), and for goats from NRC (1981).
[6] A list of the feed options used for each animal sub-system included in the model is shown in Wirsenius (2000, pp. 34, 39, 41, 54).

3. Method and data description

The purpose of this section is to describe the status of the Argentinean agri-food system, data sources, data guidelines, assumptions, and calculation procedures in the model. In the first four sub-sections, we describe and explain data flow structure, institution data sources, temporal and spatial scales, and Eco-Region division for this study. Instead in the other sub-sections we detail data assumption of food consumption, animal and vegetable food conversions, distribution and storage losses, phytomass generation, and by-products utilization.

3.1. Data flows structure

Figure 5 shows main activities which determine the biomass flows within the agri-food system. There is production of crops for human consumption and animal feed purposes, there is production of forage and use of native pasture with animal feed purposes, there is fishing and aquaculture activities for animal feed and human food purposes, and there is rearing of animals with the purpose of human food generation.

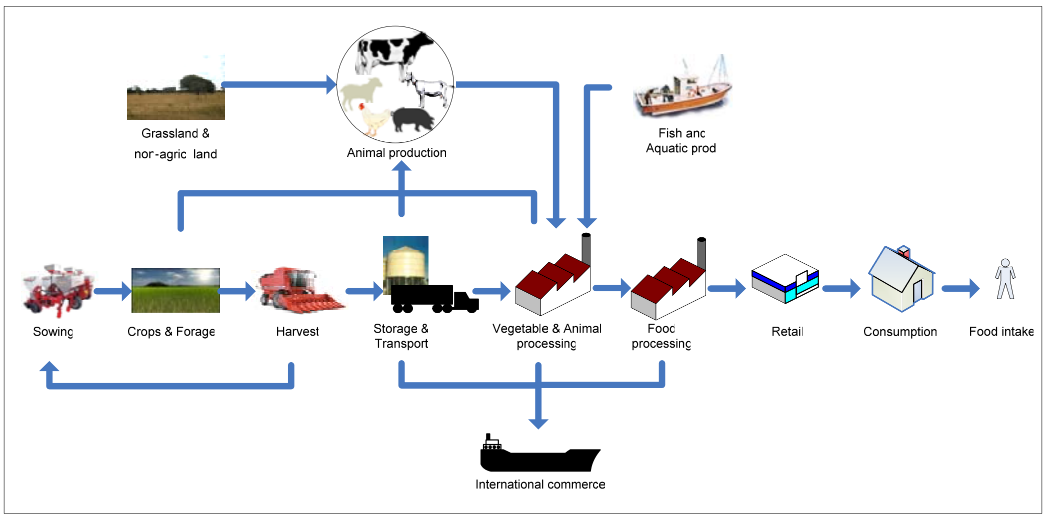

Figure 5. Biomass flows related to main activities in the Argentinean agri-food system.

With the purpose of international trade and population nutrition, activities showed in Figure 5 determine the phytomass generation, flows and subsequent efficiencies along the agri-food system into other biomass products, by-products, and residues.

To calculate and link biomass flows among activities, that is to estimate a mass balance in the agri-food system, information and data regarding each activity was needed. However, when collecting data for assumptions was found that available data was heterogeneous and significant data gaps exist for modeling the biomass flows. Therefore a number of different data-types for this study were defined with the purpose of estimating as accurately as possible the mass and energy balance of the agri-food system (see Figure 6).

a) **Statistical data**. Data collected and systematically published by official institutions. They were used mainly for major input variables, such as food consumption, international trade, and crops used as seeds.
b) **Local studies data.** Data collected from particular experiments, tests, and interviews with experts from the academic field. These data were used to make general assumptions. Forage and pasture yields, animal feed mixes, productivity parameters of livestock and crops, efficiencies in the food industry, and food waste, etc belong to these data-types.
c) **Matching data** (or restriction data) are precisely known values from statistics; therefore they were taken as reference (or restriction) values in the model. Data used as matching data in the model calculations were stock of animal pools, amounts of vegetables used for food commodities, harvested crops and conserved forages; and land used in the agri-food system.
d) **Model data output,** or model estimations. Data which is calculated from the first three data-types, and offers information to analyze and discuss

How was the model of the Argentinean agri-food system carried out? Firstly, all principal system requirements (or restrictions) were identified. These were the matching data. Second, statistical data and local data (experiments, tests, or experts suggestions) were homogenized and entered into the model. Third, the resulting equations were analyzed, and the data output interpreted. The model data output was validated against the matching data. If they did not fit well, some of the simplifying assumptions were relaxed and the model calculation repeated. This cycle of validation analysis and relaxation of the simplifying assumptions was repeated until there was a good agreement between the model data output and the matching data. In Figure 6 the data-type and data-source used in the model is shown.

3.2. Data source description

Regular data related to the food and agriculture system are collected by different institutions and published with different purposes. Therefore diverse information and data sources had to be used during this study. We briefly describe the functions and activities of most relevant institutions related to this study.

The National Institute for Agricultural Technology (INTA) is the official research institution of the agricultural activity. It works with agricultural producers, agro industries, scientific community, educational sector and environmental protection entities. The institution is located all over the country, with specific knowledge of regional and agricultural activities.

The National Secretariat for Agriculture, Livestock, Fisheries and Food (SAGPyA) is the agency responsible for making and executing plans, programs and policies regarding production, commerce, technology, food quality and public health in the field of agriculture, livestock, fishering, forest and food-industry.

Agriculture Faculties in National Universities. Their main functions are education and research within agriculture and activities related to the agri-food system.

The National Animal and Plant Health Service (SENASA) is the official agricultural health organization. Among its functions is the control the traffic and imports/exports of animal and vegetable products and by-products, agriculture crops, veterinary drugs, fertilizers and agrochemicals.

The National Institute of Statistics and Censuses (INDEC) is the technical government agency responsible for the coordination and supervision of all public statistical activities. The production of statistical information by the INDEC results from various data collection procedures (censuses, surveys, administrative and other government records).

The National Livestock Trade Control Bureau (ONCCA) is a decentralized subdivision of SAGPyA. Its function is to control the commerce of animal products when slaughtered and commercialized. It exchanges information with public and private institutions.

The Food and Agriculture Organization of the United Nations (FAO) is an international source of knowledge and information. It puts information within reach, shares policy expertise, and brings knowledge to the field.

The Inter-American Institute for Cooperation on Agriculture (IICA) focuses on information and communication of trade and agribusiness development, technology and innovation, agricultural health and food safety, sustainable rural development.

Note that other institutions such as farmers and food industries unions were used as well as information source during this study. To estimate the biomass flows of the system, it was necessary to calculate flows and link available data on the different stages of the agri-food system. Figure 6 summarizes the data-structure, data-type and data-institution sources used to depict the system.

3.3. Temporal and spatial scales

For reasons of data availability, convenience, and purpose of this study, the spatial scale defined for the analysis of the Argentinean agri-food system, was the geo-political boundaries of the country.

Regarding the temporal scale, the year 2003 was chosen as time period for this study. It was chosen according to 1) data availability in public institutions (most updated and precise obtainable data), 2) the closest date as possible to present (to avoid big changes and out of date analysis), and 3) avoid as much as possible years which may not be considered representative[7].

[7] During the years 2001-2002 the economic activity plummeted within the country. Therefore an analysis of this period may not be representative for actual situation.

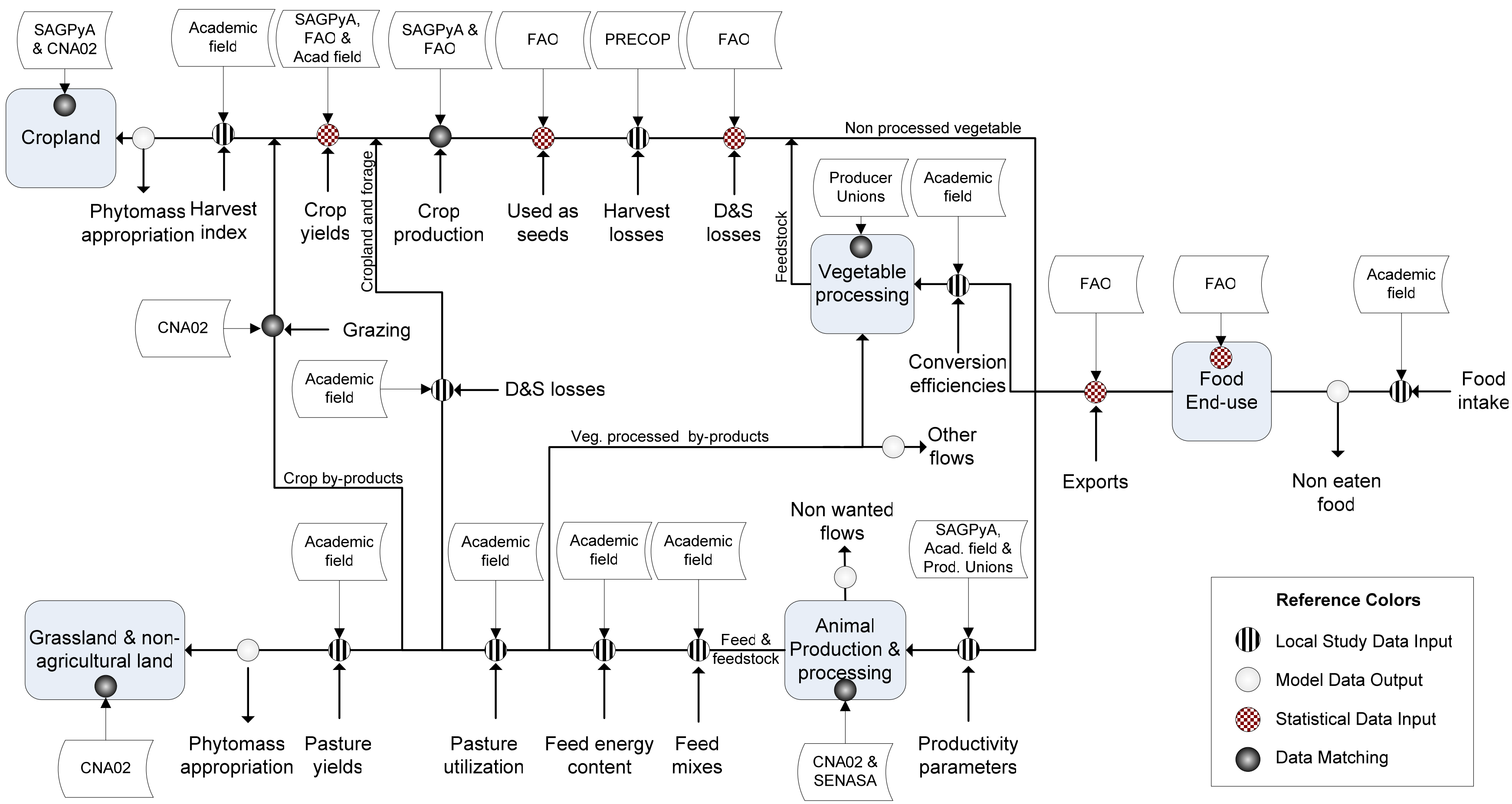

Figure 6. Relevant data flows and structure of the Argentinean agri-food model.

3.4. Eco-regional division

The country with a continent land surface of 969,464 km^2 has three main types of topographical zones: mountains in the west, plains in the central areas, and plateaus in Patagonia and in the northwestern area.

Figure 7. Map of Argentina by ER. Taken from IICA-SAGPyA (2005).

A third of the Argentinean territory is humid; a third of this consists of rainforest, another of woodland in the northeast, with the rest being humid pampas. The other two thirds of the territory are arid and semiarid regions. The main types of climates are warm, moderate, arid and cold. The territorial extension and the features of its topography determine the existence of multiple sub-climates in each of the mentioned types.

The aforementioned climatic and topographical differences between regions affect the conditions for agricultural production. That is, among regions there are variations in agriculture product-types, technology, production yields, etc; therefore the Eco-regional (ER) criterion used by IICA-SAGPyA (2005) shown in Figure 7, was adopted in this study to estimate national averages assumed in the model[8].

[8] The assumption to do such a division is based on the following criteria **Geographic:** big geographic-economic units. **Agricultural production:** areas which have one or more principal agricultural products. **Jurisdictional:** formal department's group. Depending on the main agricultural activities, department were assigned to particular ERs.

3.5. *Food consumption*

For up-stream calculations food end-use is the most important *driving variable*. Therefore detailed assumptions are crucial for accurate estimations of other agri-food system variables.

3.5.1. Food end-use

The total amount of food produced, consumed, and exported/imported was taken from FAOSTAT[9] Food Balance Sheet (FBS). This data provides estimates of quantities of food available for human consumption within the country during the chosen year. The number of people living in the country, taken from the UN Population Division, was assumed to be 38.428.000[10].

Food end-use per capita data was expressed in terms of mass and caloric terms, protein, fats, carbohydrates and alcohol content[11]. Values shown in Table 1 were assumed as average food product consumption per person.

Products	kg [as-is weight]	ME [GJ]	**Products**	kg [as-is weight]	ME [GJ]
Cereals			**Sweeteners**		
Wheat flour	98	1.389	Cane white sugar	38.3	0.620
White rice	4.3	0.063	**Tree nuts**	0.41	0.004
Maize grits, meal & flour	10.3	0.130	**Pulses**	0.93	0.014
Other grits, meal & flour	1.7	0.023	**Vegetables**	68	0.079
Starchy roots			**Fruit**	83	0.132
Cassava tubers	1.0	0.004	**Stimulants & Species**	8.2	0.018
White potato tubers	43.7	0.133	**Alcoholic beverages**		
Sweet potato tubers	4.2	0.016	Beer	118	0.157
Oil crops			**Meat (carcass)**		
Soybean seeds	0.03	0.0004	Beef cattle carcass	57.9	0.436
Groundnut pods	0.001	0.00002	Other meats carcass	2.0	0.015
Sunflower achenes	0.12	0.002	Sheep meat com.	1.2	0.011
Other Seeds	0.01	0.0002	Goat meat com.	0.2	0.002
Vegetable oils			Pig meat commodities	4.5	0.049
Soybean oil	1.8	0.068	Poultry meat commodities	19.4	0.132
Groundnut oil	0.08	0.003	**Offal & fats and heads**		0.161
Sunflower oil	9.9	0.378	**Cattle whole milk**	145	0.393
Canola oil	0.00	0.000	**Eggs**	6.8	0.038
Palm & Other oils	0.03	0.001	**Fish and seafood**	6.5	0.020

Table 1. Food end-use per capita per year. Consumption per capita and year [kg] and ME [GJ].

Note that it was considered a priority not to match values published by FAOSTAT but instead to use total food produced figures published by national

[9] FAOSTAT is a statistical database provided by FAO. Available from: http://FAOSTAT.fao.org [Accessed on 20th May]
[10] FAO explains the published value as population within the present geographical boundaries of the country. It excludes national living abroad but includes foreigners living in the country.
[11] The average amount available for the population does not necessarily indicate what is actually consumed by a person. Distribution of food consumption among population is discussed in page 89.

institutions. Therefore the food category “edible offal & fats”[12] was used as balance when matching total animal food commodities end-use.

Local Data of food ME is available in the UNL food data base[13] and the FAO data base of food composition for Latin America[14]. However with the purpose of keeping consistency and using only one data source, when assuming values for food ME for human consumption, data available from Wirsenius (2000) [15] was assumed.

3.5.2. Food intake

In section 3.5.1 statistical data of food end-use (apparent food consumption) were shown. However this is not the amount of finally food ingested by people. Two main loss categories are identified:

a) Processing industry - consumer: According to Kantor *et al.* (1997) there is correlation between food losses and the complexity of the food chain and number of times a product is handled before it reaches the consumer.
b) Consumer - food intake: Food losses among household and institutions are not equal. Engström *et al.* (2004) when comparing schools, hospitals, restaurants, etc; found differences in the amount of food wasted among institutions. In Figure 8 losses between food end-use and food Intake are shown.

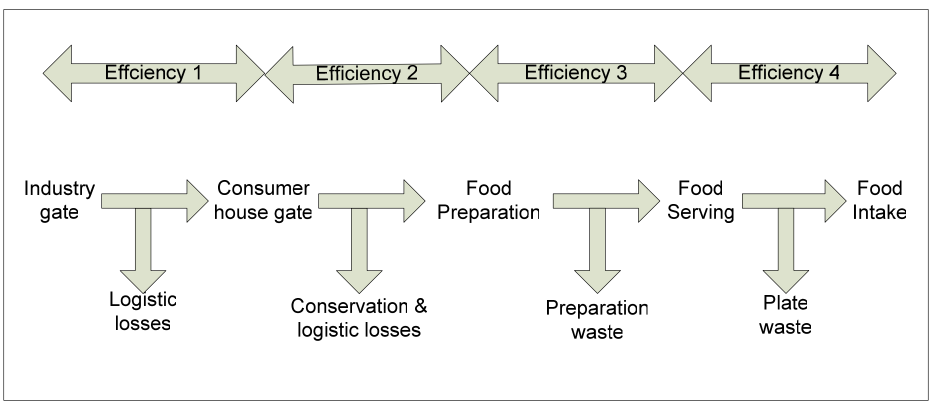

Figure 8. Food losses between end-use and intake.

Some of the food bought in stores is lost, but, why is there loss of food? Food losses may occur because over preparation, expanded menu choices, unexpected fluctuations, preparation discard, plate waste, cooking losses, spoiled leftover, and breakage, spillage, and package failure [Engström *et al.* 2004].

[12] In FAOSTAT FBS, animal fats are included as a separate item
[13] Lanús National University. Argentinean Food Composition [online]. Available from: www.unlu.edu.ar/~argenfoods/Tablas [Accessed: 20th September 2006]
[14] Latin America table of food composition [online]. Available from: www.rlc.fao.org/bases/alimento/ [Accessed: 20th September 2006]
[15] Wirsenius (2000). Assumed values on partition and composition. Table A1.I and Table A1.II. Note that Wirsenius uses standard tables of food composition from Holland *et al.* (1991).

In Table 2 estimated food waste is summarized. Due to a lack of empirical data on food waste, a modeling method to estimate losses was adopted. The average minimum dietary energy requirement [MJ/person/day] for the period 2001-2003 [FAO, 2006][16] was assumed as the amount of food intake. Subtracting to the amount of end-use the intake was estimated as the amount of food wasted[17].

Flow		Unit	Value
Food end-use	ME	[MJ/ cap. per day]	12.38
Food intake	ME	[MJ/ cap. per day]	8.12
intake / end-use		**[% ME]**	**0.656**

Table 2. Food end-use and intake per capita.

We now know from Table 2 the assumed food intake values. However it is still necessary to describe how different food categories are assumed to be wasted. Some food categories have non edible parts, others are more perishable or fragile, and therefore food wasted differs by category. Since no local information is available, assumptions were based on Wirsenius (2000, pp 63-64)[18]. In Table 3 assumed values for each food category are shown.

Category	Sub-cat.	Intake	Category	Sub-cat.	Intake
Cereals		1.00	Fruit		1.10
Starchy roots	Flesh	1.00	Stimulants		1.15
	Skin	0.00	Alcoholic beverages		1.15
Sweeteners		1.00	Meat (carcass)	Lean tissue	1.15
Oil crops		1.15		Fatty tissue	0.85
Vegetable oils		0.90	Offal & fats and heads		1.15
Tree nuts		1.15	Milk		0.90
Pulses		1.15	Eggs		1.05
Vegetables		1.10	Fish and seafood		1.15

Table 3. Values refer to intake as share of end-use, relative to the average share stated in previous table. Values are expressed in on DM basis.

Once we know the food intake and consumption, we need to assume food production efficiencies to know amounts of feedstock and feedstuff used to supply the food conversion processes. That is, in the following two sub-sections we deal with assumptions of animal food and vegetable food production.

[16] Food Security Statistics. Available from: http://www.fao.org/FAOSTAT/foodsecurity/index_en.htm [Last updated 06/10/06]. FAO publishes the Minimum Dietary Energy Requirement for different countries. In a specified age and sex group, the amount of dietary energy per person is that considered adequate to meet the energy needs for maintaining a healthy life and carrying out a light physical activity.

[17] For discussion of assumptions and biased from reality, see sub-section 0 in page 81.

[18] Food losses data assumptions were based on Kantor *et al.* (1997) study.

3.6. Production of animal food

In this sub-section, productivity parameters, feed energy requirements, and feed use in the animal food sub-systems assumptions are described. Note that national average chosen values, were estimated based on ERs used by SAGPyA-IICA (2005) weighting whenever possible[19].

3.6.1. Animal pools description

To produce a certain amount of animal commodities a pool of animals in stock is needed, which guarantees the animal food commodities flowing out of the sub-system. Therefore in this sub-section are described assumed animal stocks, productivity parameter, and carcass yields[20] for each modeled animal sub-systems. In appendix, Table 32 all productivity parameters values assumed for animal sub-systems are summarized.

Cattle sub-systems

Annual consumption of beef during 70s and 80s was over 80 kg per person. The cattle stock reached more than 61 millions heads in 1973. But since the stock peak the tendency has been a decrease in the number of heads. Consumption of this meat-type still remains substantial in the Argentinean average diet. Therefore is important to model cattle animal sub-systems as accurate as possible.

Stock

SAGPyA data was assumed as livestock guideline, and the shares per head of each category kept the proportions of the 2002 National Agricultural Census (CNA02)[21]. In the model 51 millions animals, close to the 50.9 millions cattle heads published by SAGPyA were assumed.

Slaughtered cattle

A simplification of the official cattle categories was made[22]. Therefore not all official categories were included. That is, female calves and heifers are modeled as “heifers”, and male calves, young steers and steers are modeled as “Steers”.

To estimate total carcass production and number of animals slaughtered by the beef cattle and dairy cattle sub-systems, values based on data published by ONCCA by animal category were assumed. When assuming carcass weight by category, data published by Liners[23] was used as guideline.

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[19] Chosen values try to describe as accurately as possible a weighting value of different technologies, production scales and capital intensity in different ERs of the country.
[20] It is very important to estimate precisely animal productivity parameters since they determine animal flows and feed consumption.
[21] In Appendix, Table 28 the distribution of cattle categories by ERs is shown.
[22] Cattle categories for slaughtering were changed during 2006.
[23] Mercado de Liniers. [online]. Available from: www.mercadodeliniers.com.ar [Accessed on 10th August 2006]

Cattle Beef sub-system

Because expansion of land used by crops, the main tendencies of this animal sub-system are more intensive rearing, feed lot systems, and re-location of cattle to areas where crop production is not possible. Even though nowadays less land is used to produce these animals, stock has been stable because productivity parameters have increased.

Figure 9 shows assumed values of animal flows and productivity parameters. Data sources for assumptions were ONCCA[24], suggestions from researchers, and field-literature. Note that assumptions assure matching between the model estimations and CNA02 data for the stock composition.

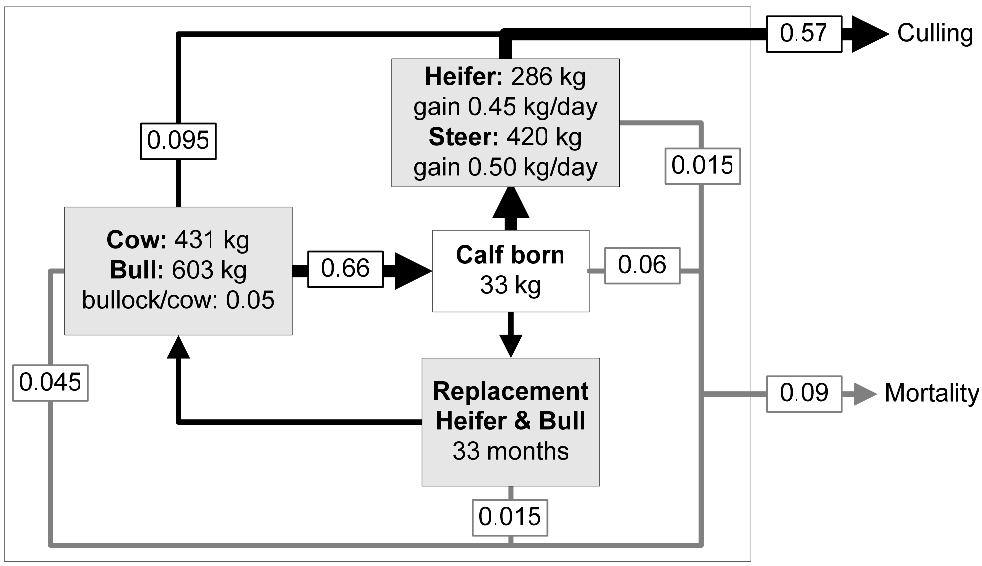

Figure 9. Beef cattle productivity parameters. Rates are expressed per year & stock of the animal category. Global culling and mortality rates are expressed per year & cows in stock.

In Table 4 assumed carcass yields values are shown. Values were estimated guaranteeing consistency among all productivity parameter values. They were based on guidelines published by Di Marco (2002), carcass weights by animal category ONCCA data, and averages live weight Liniers data.

Cows	Bulls	Steers	Heifers
50%	56%	56%	55%

Table 4. Carcass yield for beef cattle categories [as-is weight]

[24] Official data on the slaughter of cattle published by ONCCA can be considered as “real”, since informal activity (animals eaten in the countryside) is almost negligible.

Cattle milk sub-system

According to CNA02 there were 14 thousands dairy farms with an average of 140 cows per farm, mainly located in Pampeana ER. In the last ten years Argentina had reached a considerable consumption of dairy products per capita (230 equivalent liters per year). Consumption of milk decreased considerably in 2002, however after the bottom trough, growth has been substantial. According to FAOSTAT during the period analyzed there was in stock 2 millions milk cows.

In Figure 10 animal flows and assumed values of productivity parameters are shown. Assumed values were chosen assuring consistency for the whole sub-system. Note that since steer/heifers are milk breed, assumed values for slaughtering live weight were considered 10% lower than average beef steer/heifers breeds. The number of bullocks per milk cow is around 2%, however a slightly higher value was assumed for matching with CNA02 data[25].

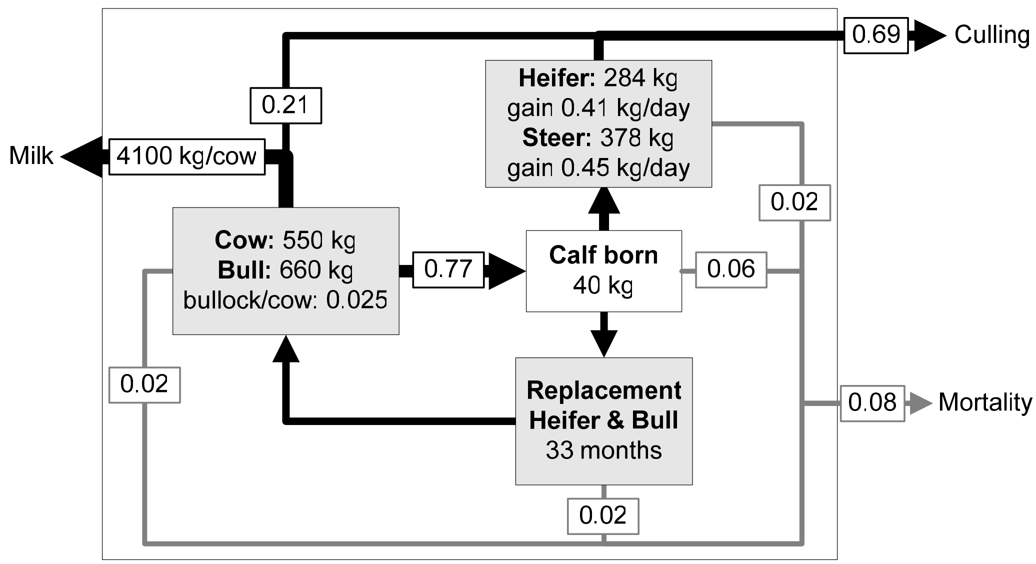

Figure 10. Milk cattle productivity parameters. Rates are expressed per year & stock of the animal category. Global culling and mortality rates are expressed per year & cows in stock.

The chosen values for carcass yield are stated in Table 5. To assume values Di Marco (2002) data were used as guidelines, matching total carcass production and number of slaughtered animals by category with ONCCA data.

Cows	Bull	Steers	Heifers
49%	57%	56%	55%

Table 5. Carcass yield for milk cattle categories [as-is weight]

[25] The assumed value of cow culling rate may be low if compared to expertise estimations. A cow can live 12 years, and even 20, but the average value for the model does not reach 4 years. According to Capitaine Funes and Vater (2003), the flow-in (replacement rate of heifer entering to the sub-system per year) is close to 23% of the milk cows in stock. At the same time the assumed value of cow mortality is slightly higher than CNA02 value, which is 1.7% of dead animals (older than one year) per total animal in stock.

Sheep sub-system

During the last 40 years the stock of this animal sub-system was considerable reduced because of advance of cropland and cattle activity. But because of actual restriction of cattle meat exports, wool prices increase, and official incentives to recover the activity, nowadays there is a repopulation of the sheep stock. That is, the “sheep law”[26], the “Prolana program”[27], currency exchange rates favorable for exports, combined with continuously increasing prices of the synthetic fibers, made sheep rearing a profitable activity[28].

Stock

According to SAGPyA[29], there were 13 millions sheep in stock for the year 2003. According to FAOSTAT however, there was a stock of 12.5 millions animals, close to the 12.56 millions censed in CNA02. In the model a total stock of 12.5 millions heads for this sub-system was assumed.

Productivity Parameters

Based on UNLZ and UNRC Sheep Departments suggestions and stock distribution by ERs shown in Table 29, medium values of productivity parameters were assumed. A summary of assumed values for this animal food sub-system are shown in Figure 11.

Note that milk products exist in reality but are not considered in the model, and the slaughtered categories were simplified. An average live weight for the category “ram/ewe hogget” based on existing different sub-categories was assumed. Average shares for the period 2000-2005 of sub-categories slaughtered heads were taken from SENASA. As well live weights were based on SAGPyA-IICA (2005) for lamb sub-category, and on own assumptions for the other two sub-categories.

Assumed carcass yields for sheep for are shown in Table 6. Assumed values were based on data matching among carcass production, total stock, productivity parameters, and guideline values suggested by Lynch et al.[30].

Ewes	Rams	Ram hogget	Ewe hogget
43%	43%	51%	51%

Table 6. Carcass yield for sheep categories [as-is weight].

[26] Law 25.422, was created in the year 2001 to promote the recovery of the sheep activity in the country.
[27] Prolana, is a program created by SAGPyA to promote improvement in wool quality.
[28] The production of meat for the internal and external market, which is far from being saturated, is an interesting alternative for the animal production system, considering that sheep complements beef cattle production, when they pasture in open fields, raising pasture utilization of grass and crop by-products.
[29] Departamento de Ovinos y Lanas. SAGPyA. *Existencias*. [online]. Available from: http://www.sagpya.mecon.gov.ar/ [Accessed on 10th December 2006]
[30] Lynch, Gloria and Simonetti Laura. Cátedra de Ovinos. UNLZ. [Pers. comm. July 2006]

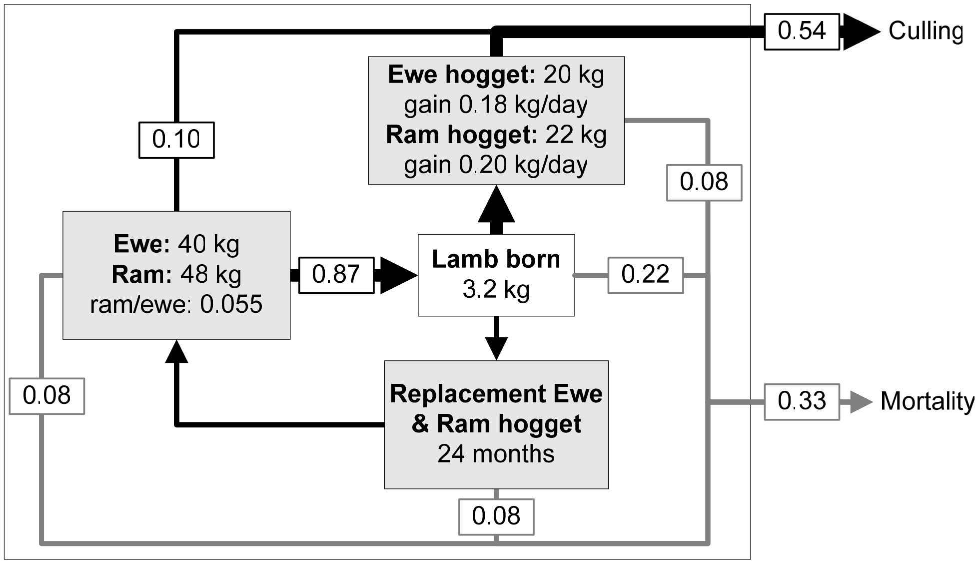

Figure 11. Sheep productivity parameters. Rates are expressed per year & stock of the animal category. Global culling and mortality rates are expressed per year & ewes in stock[31].

Goat sub-system

The dominant goat breed in Argentina is called Criollo. It was brought to the country 400 years ago and gradually adapted to the local conditions. Goat production is significant in some regions as the only choice to animal production, and in others as a complement to system-extensive beef cattle production.

According to Roig (2003) goats production can be defined as either subsistence, extensive or sedentary. Labile environment, non abundance of grasses and water, often create environmental and socioeconomic problem in this animal sub-system production, and as a consequence significantly lower productivity values than potentials. In some regions of the country, such as Oasis Cuyano ER the situation changes, and there are farms with more intensive production and better productivity values.

<u>Stock</u>

In the CNA02 were censed 4.06 millions animals for this sub-system, however for the analyzed year FAO publishes 4.2 millions. With a carcass production 9.6 Gg and the productivity parameters showed in the following page, in the model it was assumed a consistent value of 4.04 millions animals in stock[32].

[31] Lamb birth weight is estimated to 3.2 kg for all regions, reaching a live weight at slaughter in the range of 10 to 25 kg. There is a strong seasonal consumption during the months of December to January, motivated in the higher availability of weaned lambs, as a consequence of animals being born in the spring; and a strong demand of this type of meat for Christmas and New Year parties.
[32] Note that an assumed stock animal is an average for the year, since variations of stock are considerable during the year.

Productivity Parameters

Production of goat meat is mainly oriented towards slaughtering goat kids at or before weaning. Goat lambs are raised based on milk from the breeding doe. From region to region live weights at slaughter are in the range of 8 to 14 kg, with an age of 30 to 100 days. The carcass weight is in the range of 4 to 9 kg, with low fat content and good nutritional qualities. The slaughter of goats is mainly done in farms for domestic consumption, and only a very low percentage is industrialized slaughter[33].

In Figure 12 animal flows and productivity parameters assumed values are shown[34]. Note that goat milk products exist in some farms; however this is not considered in the model. The chosen values were based on suggestions from Santiago de Gea[35], Pondé[36] and goats distribution by ER from CNA02 data (shown in Table 30). With suggested values of 130 gr. of live weight gain per day for doe/buck kids, in the model were assumed considerable lower values with the purpose of matching the stock composition by animal categories and the total amount of animals in stock.

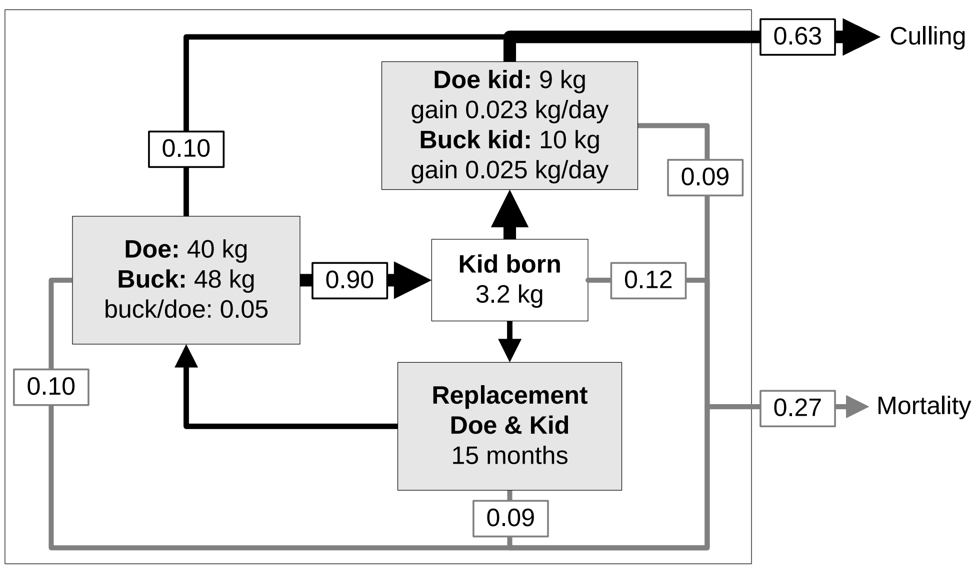

Figure 12. Goats productivity parameters. Rates are expressed per year & stock of the animal category. Global culling and mortality rates are expressed per year & does in stock.

[33] According to TodoCabra, Official slaughtering animals is not more than 15%. [online]. Available from: http://www.todocabra.com.ar/ [Accessed: 20th Agust 2006]
[34] Since most of this activity is not registered data varies immensely from different sources. Therefore there could be an underestimation of total carcass consumption. In the model and extra 20% of goat carcass generation (end-use) was assumed, matching stock with FAOSTAT data. Since doe/buck kids have a very short life, what is important when matching animal stocks are doe, buck, and replacement doe/buck kids categories.
[35] Santiago de Gea, Ginés. Cátedra de Ovinos y Caprinos, UNRC. [Pers. comm. September 2006]
[36] Pondé, Marcelo. Sector Caprino, SAGPyA. [Pers. comm. July 2006]

There are no official data on live weights at slaughter for these animals. Since the live weight for buck/doe kids varies considerably, a representative value was estimated for this category. It was combined average slaughter live weights[37], with data for type of animal slaughtered by sub-category[38].

Assumptions of carcass yield for goats were based on data from a goat meat processing plant[39], Vera *et al.* (2005) and Leguiza *et al.* (2005). The average carcass yields chosen for the model, for each category, are shown in Table 7.

Does	Bucks	Buck kids	Doe kids
42%	42%	47.5%	47.5%

Table 7. Carcass yield for goat categories [as-is weight]

Pig sub-system

Pig production in the country was initiated by a significant number of small farm producers, who were rearing pigs in open fields. To feed the animals farmers used their own crop production, by-products and food residues. However, over the last number of years this is changing and intense-system pig production on a large scale is increasing. Today the pig production is becoming an important agricultural activity and not longer an alternative to grain sailing when prices are relatively low.

Stock

Pig stock data vary considerable among sources. The CNA02 counted 2.2 millions animals whereas according to FAOSTAT there were 1.5 millions heads during the year 2003. Therefore only breeding sows category with guideline values was matched. Suggestions from SAGPyA[40] and Biofarma[41] are in the range of 160 to 200 thousands of reproducers, and according to productivity values assumed in the model, 133 thousand is estimated for the analyzed period.

Productivity Parameters

In Figure 13 animal flows and productivity parameters assumed values are shown. Assumed values for this sub-system were based on suggestions by Guerra[42], and Dimeglio & Arrieta [43]. When estimating productivity parameters, suggested data were weighted using distribution of the breeding sows stock by farmer-type producers: a) big producers 45%, b) producers in open fields 22.5%, c) small producers 12.5%.

[37] Data from SAGPyA-IICA (2005).
[38] Oficial data provided by SENASA
[39] San Javier goat meat processing plant. Villa Dolores, Córdoba. Note that available data for carcass yield includes head for kids, but excludes head for big animals. In the model goat carcass yields were expressed without head.
[40] Papotto Daniel. SAGPyA. [Pers. comm. Agust 2006]
[41] Dimeglio, Sergio and Arrieta, José Carlos. Biofarma S.A. Company. [Pers. comm. September 2006]
[42] Guerra, Carlos. Grupo de Trabajo Porcino. INTA-Pergamino. [Pers. comm. July 2006]
[43] Dimeglio, Sergio and Arrieta, José Carlos. Biofarma S.A. Company. [Pers. comm. September 2006]

Average live weight at slaughter changes depending on animal age. For swine category 100 kg live weight was assumed. To estimate such assumption, four official sub-categories from SENASA data[44] were considered with averages for the period 2000-2005.

Regularly, in Argentina carcass yields are given with head and feet included. Guerra[45] suggests values in the range of 80% for small farmers, to 85% for big farmers. Alternatively Dimeglio & Arrieta suggest values from 80% to 83%[46]. Based on suggested values, an average carcass-side yield (head-off, skin-off and feet-off carcass) of 58% of live weight was assumed [as-is weight].

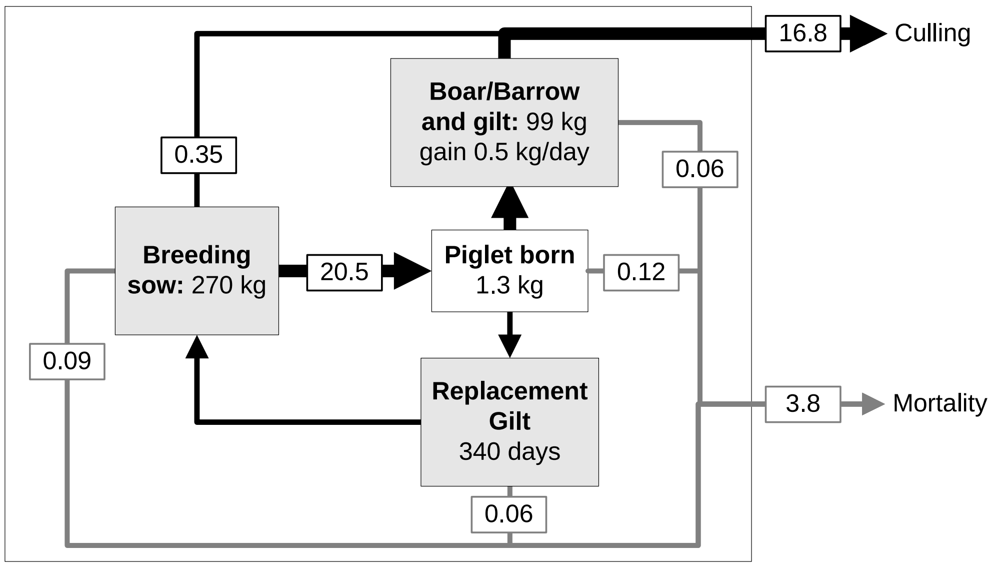

Figure 13. Pig productivity parameters. Rates are expressed per year & stock of the animal category. Global culling and mortality rates are expressed per year & breeding sows in stock.

Poultry sub-systems

Buenos Aires and Entre Rios provinces are the main producers of this animal meat-type with more than 95% of total production. The year 2003 resulted in an improvement for the poultry sector in the country. The sector showed a recovery in the production of meat and eggs. The tendency is to increase production for internal consumption and exports. Still the sector may improve productivity and grow a lot.

<u>Stock</u>

FAOSTAT publish data on poultry stock. However these sub-systems stocks may change substantially over the year, because of the animal's short life and high reproducibility. Therefore in the model stock was not matched. Instead there is matching of the amount of eggs and carcass production.

[44] These slaughtered categories are defined by SENASA
[45] Guerra, Carlos. Grupo de Trabajo Porcino. INTA-Pergamino. [Pers. comm. July 2006]
[46] The more intense is the activity, the more is improved the genetic and an adequate feed, and as a consequence higher carcass yields.

Meat-type chickens sub-system

In the model meat-type chicken carcass is not only chicken broiler meat; but also includes duck meat, goose meat and turkey meat. The consumption of this meat-type is considerable, and tends to increase.

Productivity Parameters

In Figure 14 shows animal flows and productivity parameters assumed values for this sub-system. Since data availability is disperse in different sources and not always homogeneous, assumed values were based on guideline values suggested by RENAVI[47], Avimetria[48], and statistics from CAPIA[49].

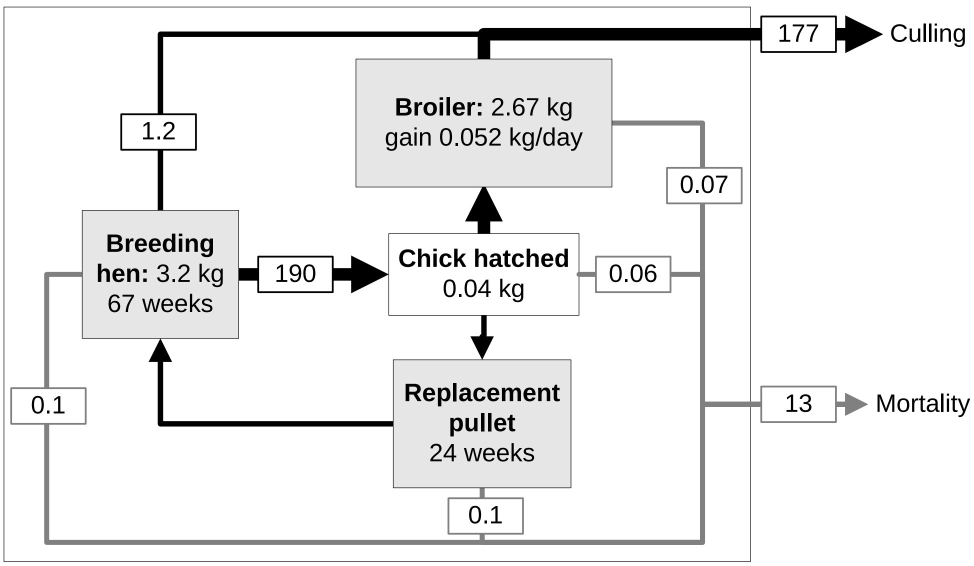

Figure 14. Meat-type chicken productivity parameters. Rates are per year & stock of the animal category. Global culling and mortality rates are per year & breeding hens in stock.

Leghorn-type chickens sub-system

Leghorn-type chicken production is considerable in the poultry sector. In this sub-section assumed values are detailed.

Productivity Parameters

Animal flows and productivity parameters assumed values for the whole leghorn-type chicken sub-system are shown in Figure 15. No breeding males are included since they account for an insignificant amount of the total sub-system stock. Assumed productivity values were estimated based on SAGPyA[50] and CAPIA (2005).

[47] Lamelas, Karina. RENAVI, Dirección de Ganadería, Aves. SAGPyA. [Pers. comm. Agust 2006]
[48] Micheluzzi, Luis. Avimetría. [Pers. comm. October 2006], and Informe Estadístico Agust 2006.
[49] Argentine Union Producers of Poultry Products (2006). Statistics [online]. Available from: www.capia.com.ar [Accessed August 2006]
[50] Lamelas, Karina. RENAVI, Dirección de Ganadería, Aves. SAGPyA. [Pers. comm. Agust 2006]

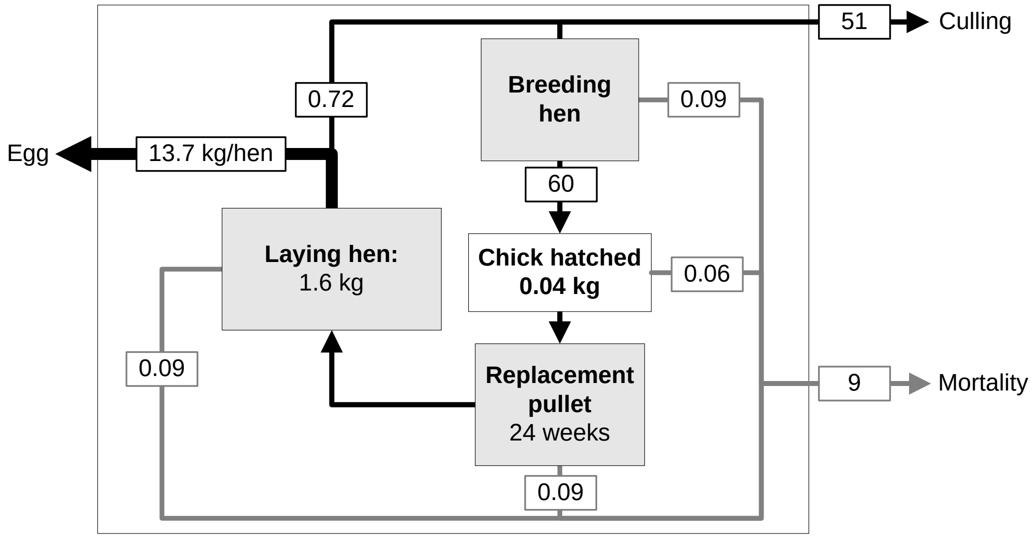

Figure 15. Leghorn-type meat productivity parameters[51]. Rates are per year & stock of the animal category. Global culling and mortality rates are per year & breeding hens in stock.

No official data regarding carcass yield values were found. Therefore, based on guideline values, the average carcass yield chosen for poultry, that is meat-type and leghorn type chicken sub-systems, was 73% of live weight [as-is weight].

Other animal carcass

As a way of matching the total meat consumption, the model included “Other animals” sub-system[52]. According to FAOSTAT other meats carcass as equine meat accounted for 55.6 thousand tons, game meat for 48.5 thousand tons, and rabbit meat for 7.2 thousand tons. Horses are used for draught work and sporting activities. Some are slaughtered after their “active life”. Animals coming from game are part of nature. They therefore do not appropriate phytomass for human food[53].

These animal sub-systems should be considered as system-external inputs. However in the model they were considered within the agri-food system boundaries. That is, an artificial animal sub-system to depict the biomass flows by animal food as close to reality as possible was created. This animal sub-system represents only 2% of total meat consumption. Therefore does not affect global values significantly. Productivity parameters and carcass yields were assumed to have similar values to the beef cattle sub-system.

[51] Amount of eggs produced per laying hen is a consequence of chicken meat, eggs and animal feed prices, the laying hens stock varies with the time. If the equation feed/egg is not economically favorable, there is a tendency for laying hens to not go through to the second phase, and instead are slaughtered.
[52] See the concept of matching-type data in page 7.
[53] Exceptions can be breeding animals for game activity. In this case they would appropriate phytomass for human food consumption.

3.6.2. Feed energy requirements

In this sub-section we deal with assumed values of energy requirements for animal commodities production. That is, an animal sub-system requires feed energy to produce a certain amount of products. To estimate such energy demand, assumptions were divided in two main energy requirement categories; base and additional energy requirement.

Base energy requirements

Based on total animals in stock, stock compositions and productivity parameters for each animal sub-system defined in the previous sub-section, Table 8 shows the base energy requirement for producing animal commodities. That is, the base energy requirements for each sub-system. Note that for all ruminant sub-system, the values only refer to base energy requirement. The extra energy expenditure by these animals when grazing is discussed further on the following page.

Values shown in Table 8 represent the actual conversion efficiency of the feed eaten by animals. However, note that these conversion efficiencies can not be compared among sub-systems straightforward, since feed energy units are different and composition of commodities are in as-is weight terms.

Commodity	**Unit**	MJ / kg of commodity as-is
Milk cattle		
Cows, bulls & replacement heifer/bullock	NE_l	6.7
	NE_m	1.5
	NE_g	0.4
Dairy steer & heifer for carcass	NE_m	75
	NE_g	15
Beef cattle	NE_m	211
	NE_g	20
Sheep carcass	NE_m	405
	NE_g	21
Goats carcass	NE_m	651
	NE_g	27
Pig carcass	ME	76
Eggs and hen carcass	ME	35
Meat-type chicken carcass	ME	40

Table 8. Estimated values of feed energy requirement per amount of commodity generated.

Grazing additional energy expenditure

Ruminant sub-systems are mainly in open fields. Therefore animals have to walk to get water and feed. The topography and climate where animals pasture thus induce extra energy demand for maintenance. In the model the extra energy needed for maintenance was contemplated. According to Di Marco & Aello (2003) when grazing on surfaces with high APNPP (Above ground Phytomass Net Primary Productivity) the extra maintenance energy is in the order of 8 to 12%. Against this in areas with low APNPP and bad nutrition composition with severe phytomass restriction, the extra energy needed is in the order of 25 to 30%. In Table 9 values assumed in the model are shown.

Pasture Type	Extra Energy [%]
Cropland pasture	0.10
Permanent pasture (Extra Pampeana ER)	0.20
Permanent pasture (Pampeana ER)	0.10
Non-agricultural herbage	0.25
Crop by-products	0.10

Table 9. Extra energy requirements assumed when pasturing. Values are extra % of energy when grazing, and are expressed as share of the base maintenance requirement (NE_m).

Note that crop by-products are regularly grazed directly by ruminants, but sometimes removed and stored as hay before reach the animals. In the model was assumed that ruminants graze crop by-products, and make the same effort to graze crop by-products compared cropland pasture.

3.6.3. Feed use

In this sub-section the use of feed for each animal sub-system are described. Assumed values of feed use were based on complete feed balances with respect to energy. This means that for each animal sub-system, the energy content of the feed intake complies with the estimated feed energy requirements. The feed balances are achieved by performing an iterative adjustment of the feed mixes. This calculation includes matching and tuning with available data, and to some extent also with nutrient density requirement data[54].

Nutrient density requirement data

The feed eaten by an animal needs to have a certain nutrient density in order to achieve a productivity target. When choosing the average feed mix for each animal sub-system, priority was given to the feed available, as a result of crop availability. In addition to this, Table 10 shows guideline values[55] used to know if assumed feed mix composition were in accordance with “theoretical” nutrient requirements for each animal sub-system.

[54] See page 7 of this study and Wirsenius (2000, pp. 77-79)
[55] Guideline values were taken from the ALBIO model.

Animal category and sub-system	Unit	Guideline values	Study outcome
Milk cattle			
Dairy cattle cow	NE_l	5.6	6.3
	Prot.	13%	14%
Dairy cattle replacement	NE_m	4.3	5.6
Dairy cattle steer & heifers	NE_m	4.7	5.6
Beef Cattle			
Cow, bullock & replacement	NE_m	4.0	5.2
Beef cattle steer & heifers	NE_m	4.7	5.6
Sheep			
Ewe, ram & replacement	NE_m	3.6	5.0
Ram & ewe hogget	NE_m	5.2	5.5
Goats			
Doe, buck & replacement	NE_m	3.6	4.1
Buck kids & doe kids	NE_m	4.6	4.2
Pig	ME		14.4
	Prot.		21%
Egg	ME		13.8
	Prot.		24%
Chicken	ME		14.3
	Prot.		26%

Table 10. Nutrient density requirements guideline and outcome values from this study. Energy densities are given in MJ/kg DM, and protein densities in percentage of total DM.

Allocation of products

Feed use data is mostly given for livestock as an entire group. For example, FAOSTAT compiles estimates of feed consumption only for livestock as whole group only, not for separate animal sub-systems. Similarly, within the country, there is no institution with detailed information of feed assignment to different animal sub-systems[56]. However the lack of data was covered with modeling assumptions of feed assignments to different animal categories.

Allocations were made following hierarchies, based mainly on overall nutrients requirements and feed suitability, with respect to the character of the digestive system of each animal sub-system. In addition, for internally generated by-products, the allocation was guided by availability and quality of the substituted product. The priorities, as share of feed mix of each system, were:

For **Cereal**, priority was given to egg and chicken meat sub-system, since these feed mixes are less flexible than other animal feed mixes. Secondly priority was given to pigs, and later dairy and beef cattle sub-systems.

For **Starchy roots**, cassava is the only product of this category used as feed, and priority was given to pigs and later to cattle. However, consumption of these crops as animal feed is almost nonexistent.

[56] 1) The only study which covers these data description, was published in 1998, “Maíz Argentino en Cifras” by SAGPyA. An analysis of maize allocation as animal feed is done, but nowadays it is out of date. 2) Cafab (Cámara Argentina de Fabricantes de Alimentos Balanceados) has a project to make a survey to animal producers in order to know more precisely in which animal sub-systems the main feed crops are used. 3) The CNA02 provides information about the number of animals fed with harvested/conserved forage and concentrated products. However no quantities are specified.

Non-fibrous cereal milling by-products were treated as a substitute to cereals, and follow the same priorities as cereals. Since there was enough cereals products for egg, chicken and pig sub-system, the surplus of non-fibrous cereals milling by-product was allocated equally between all five animal sub-systems.

Some of the **other non-fibrous by-products** were solely allocated to cattle and some solely to pigs[57]. Molasses was treated as substitute to cereals products, following the same principle of allocation.

For **Protein supplement by-product** (protein meals), priority was given to eggs, chicken meat and pig sub-systems, since they have high protein requirement, and their diets are not flexible when done on an industrialized scale. Surplus was allocated to milk cows and beef steer/heifer with equal priority.

Crop by-products were allocated to the ruminant sub-systems, proportionally to energy requirement. When assigning to each ruminant sub-system the amount of these fibrous by-products the ER distribution of animals was not contemplated.

Feed balance calculations

The feed balance calculations were carried out in the following way:

- For feed categories included in FAOSTAT FBS, assumed model values on the *total* feed use for the entire animal system were matched with the corresponding values in the FBS.
- For feed categories not included in the FBS, such as pastures, crop by-products, harvested/conserved forage, etc, model values were based on various sources and approaches.
  - For protein supplement, cereal and oil crops milling by-products, assumptions were based local sources figures of production and international trade.
  - Amounts of food residues used as feed was assumed based on general guidelines of share in pigs feed mix of this feed category.
  - Crop by-products were assumed according to surface grazed by ruminants from CNA02 data.
  - Harvested/conserved forage crops were assumed according to Clemente[58] suggestions. For cropland pastures assumptions were based on CNA02 land use for these crop-types.
  - Permanent pasture feed were assumed according to the figure of CNA02. That is, according to the grazed surface by ruminants, the pasture index and the average pasture yield per unit of surface.

[57] More detailed information needs to be collected, to give a precise allocation of these by products.
[58] Clemente, Gustavo. Private consultant. [Pers. comm. October 2006].

Feed nutrient densities data

Nutritive values of feedstuffs were based on global and regional data available in Wirsenius (Table A1.I, 2000) complemented with typical Argentinean values from different literature sources. In addition Jaurena et al. (2006) and Guaita et al. (2005) were used for ruminants' feeds products and some by-products. As well as this, D'Ascanio et al. (1992) was used for by-products feed nutrient assumption values. Annual and perennial cropland forage nutritive values were taken from Gaggiotti et al. (1996).

Ruminant feed mixes

In Table 11 assumed feed composition for each ruminant sub-system[59] are shown. Assumed values were based on a combination of feed mixes in proportion to the animals in stock by ER, products and by-products available by ER, considering proper matching of land use for cropland pasture (annual and perennial), harvested/conserved forage, permanent pasture, and non-agricultural land feedstuff.

The assumed crop by-products grazed by ruminants was estimated through the allocation method described in page 27. The amount assigned to each sub-system comes as a result of the amount of crop by-products surface grazed by ruminants. A share in the feed mixes in the order of 4 to 5% of crop by-products for all ruminants was estimated with 15% grazing of the total crop surface[60].

Some constraints were used to tune the feed mixes. Since concentrated products and harvested/conserved forage were known values, and crop by-products and non-agriculture land pasture were assumed with defined criteria, cropland and permanent pasture were used to tune the global values demanded by the ruminant sub-systems. That is, APNPP and DE of these feedstuffs categories can vary by ER. Therefore these two variables were used to assure an adequate diet and a matching of total land grazed by ruminants.

[59] The table only shows feed categories but not feed products. Amounts of feed products assigned to each animal sub-system are not specified in this report. For more details of assumption of each animal diet, please contact the author.

[60] The surface of crop by-products grazed by ruminant sub-systems is estimated with CNA02 data.

Animal sub-system and category	**Products**	Concentrate products	Conserved forage	Cropland pasture	Perm. pasture & browse	Non-agricultural herbage	**By-products**	Non-fibrous by-products	Fibrous by-products	Protein suppl. by-products
Cattle milk										
Dairy cattle cow	0.96	0.16	0.42	0.38	0.01	0.00	0.04	0.01	0.02	0.00
Dairy cattle replacement	0.91	0.02	0.40	0.49	0.00	0.00	0.10	0.00	0.10	0.00
Dairy cattle bulls & heifers	0.92	0.02	0.25	0.45	0.21	0.00	0.08	0.00	0.08	0.00
Cattle carcass										
Cow, bullock & replacement	0.94	0.00	0.15	0.05	0.69	0.05	0.06	0.01	0.05	0.00
Beef cattle bulls & heifers	0.94	0.02	0.25	0.45	0.23	0.00	0.06	0.00	0.05	0.01
Sheep										
Ewe, ram & replacement	0.95	0.00	0.00	0.09	0.76	0.10	0.05	0.00	0.05	0.00
Ram & ewe hogget	0.76	0.00	0.00	0.09	0.57	0.10	0.24	0.18	0.06	0.00
Goats										
Doe, buck & replacement	0.94	0.00	0.00	0.00	0.24	0.70	0.06	0.01	0.05	0.00
Buck & doe kids	0.99	0.00	0.00	0.00	0.29	0.70	0.01	0.00	0.01	0.00

Table 11. Feed mix (ration) for animal production. DM basis.

Milk Cattle Diets

The feed mix was chosen by trying to represent the average dairy farm. To that end [Zinder and Magnasco, 2003] was used with samples of dairy farms located in Abasto Bs As, West Bs As, Mar y Sierras Bs As, Center Santa Fe and South Córdoba (milk producer most representative regions). Guideline values were used to assume harvested/conserved forage, cropland pasture, and concentrated products shares in the feed mix, considering always matching of total land use by these animals.

This animal sub-system is located mainly in productive areas, where only permanent pasture and cropland are available as feed options. Therefore the feed category non-agricultural land was considered to be null.

Beef Cattle Diets

Beef cattle sub-system has many possible inter and intra different feed mixes by ERs. However three mainstreams feed mixes can be defined. That is, reproducer and replacement feed mix, heifers/steers feed in open fields with or without supplement, and heifers/steers feed in lots.

Assumed values of average feed mix for the beef cattle sub-system were based on values guidelines suggested by Peuser[61], Colombatto[62], and Aello & Di Marco[63]. Guideline values were shares of harvested/conserved forage, permanent pasture, cropland pasture, and concentrated products in the feed mix.

[61] Peuser, Ricardo. Cátedra de Nutrición Bovina. UNC. [Pers. comm. July 2006]
[62] Colombatto,.Darío. Cátedra de Producción de Carne Bovina. UBA. [Pers. comm. September 2006]
[63] Aello, Mario and Di Marco, Oscar. INTA Balcarce. [Pers. comm. November 2006]

Non-agricultural land category was assumed to represent only 5% of the feed mix of reproducers and replacement cattle, which makes a total share for the whole sub-system of around 3.5%.

Sheep Diets

These ruminants are mainly feed with permanent pasture species. Concentrated products and harvested/conserved forage are only a very small share in some regions. However no use of them as feed for this sub-system was assumed.

Use of cropland pasture to feed sheep takes place mainly in the Pampeana ER. This kind of practice is common at farms which combine different agriculture activities, such as crops production with bovines and sheep rearing[64]. In the model it was assumed that 25% of the sheep diet in the Pampeana ER consists of cropland pasture, which corresponds to 9% of the global average diet.

For the permanent pasture feed category shares of 25%, 90% and 100%, in Pampeana, Patagonia and Mesopotamia ERs in the feed mixes were assumed, which gives a country average value of 75%. Regarding the non-agricultural land feed category was assumed to be 10% of the share in the feed mix.

Goat Diets

Almost all goats are raised in an extensive and subsistence manner, and the feed supply consists of pastures and herbs from agriculture marginal areas. As can be seen in Table 30 goat production is located in the south, north and west of the country, mainly on non-agricultural land, and generally in predominantly semi-arid areas. The vegetation of ERs where goats mainly are reared consists of woody permanent pasture, bush land, scarce grass, and land with very low vegetation cover.

In the model the feed mix was assumed to be 25% of permanent pasture, with 70% coming from grazing in non-agricultural land (phytomass from wooded, bushy and hilly areas). The other 5% of diet corresponds to crop by-products.

Monogastric feed mixes

In Table 12 feed mixes for monogastric animal sub-systems are shown. Note that feed mixes of these animals are complex and include products which contribute to a balanced nutrition. However, only biomass products and by-products with energy content were considered in the model.

[64] After crops are harvested, cattle pasture crop by-products on the field, and later sheep pasture what was left by bovines, as a way of improving pasture efficiencies.

Animal sub-system and category	**Products**	Concentrate products	Protein suppl. products	**By-products & residues**	Non-fibrous by-products	Protein suppl. by-products	Food residues
Pig	0.72	0.71	0.01	0.28	0.01	0.25	0.02
Egg	0.71	0.63	0.08	0.29	0.01	0.28	
Chicken	0.78	0.55	0.23	0.22	0.01	0.21	

Table 12. Feed mix (ration) for animal production. DM basis.

Pig Diets

The average feed mix shown in Table 12 was assumed based on typical rations for all pig categories. Assumptions were based on Pinheiro Machado (2005) and guidelines values suggested by Guerra[65], and Dimeglio and Arrieta [66].
For rearing pigs different feed sources for substituting cereal grains are available. The extent of the use of cereal grains largely depends on the relative price of grains and pig carcass. That is, the share of concentrate products in pig diets is in the range 50 to 80%, and in the model a share of 70% of concentrate products in an average feed mix was assumed.

Protein supplement by-products were assumed to represent 25% of the average diet. This feed category is mainly based in oil crop by-products (soybean meal, sunflower meal, etc.) and meat-bone meals. The rest of the diet was based mainly on other minor contributions from non-fibrous by-products (1.5%), food residues (2%), and protein products (1.3%).

Chicken Diets

To assume feed mixes for leghorn-type and meat-type chickens Bina[67], and Dimeglio & Arrieta[68] were consulted. Considering typical rations and possible range of variation (depending on feed prices and feed availability), a medium feed mix for each chicken sub-system was estimated.

Table 12 shows values assumed for leghorn-type and meat-type sub-systems. For low-intensive reared chicken, diets are relatively flexible and depend on availability different mixes may be chosen with the possibility to substitute large parts of grains for other less costly products. However for intense poultry production in which high-energy feedstuffs are crucial, there are only very standardized feed mixes.

[65] Guerra, Carlos. Grupo de Trabajo Porcino. INTA-Pergamino. [Pers. comm. September 2006]
[66] Dimeglio, Sergio and Arrieta, José Carlos. Biofarma S.A. Company. [Pers. comm. September 2006]
[67] Bina, José. Agroimperio SRL Company. [Pers. comm. September 2006]
[68] Dimeglio, Sergio and Arrieta, José Carlos. Biofarma S.A. Company. [Pers. comm. September 2006]

3.6.4. Use of litter for bedding in animal confinements

Animal bedding is only substantial in poultry, mainly of meat-type chickens, but is also used in the pig sub-system in small amounts[69] to some extent. Considerable amounts are used for other animals than in the agri-food system. That is external animals, i.e. horses in confinement.

Litter use close to zero for all ruminant sub-systems was assumed, since they are outdoors (exceptions are animals locked up in lots to mate or breed). Leghorn-type chicken was assumed to not use bedding materials. For meat-type chickens (broilers) and pigs assumptions were based on Wirsenius (2000, p. 86). Biomass by-products other than cereal straw such as rice husks, sawdust, sunflower straw, are often used as bedding. The choice depends on availability in the area. In the model cereal straw is the only flow depicting bedding material. The chosen values by animal sub-system are shown in Table 13.

Animal sub-system	Amount
Cattle milk	0.02
Beef cattle carcass	0.01
Sheep carcass	0.00
Goat carcass	0.00
Pig carcass-side	0.20
Chicken egg	0.00
Meat-type chicken carcass	0.01

Table 13. Cereals straw used in average for entire flock (kg DM/head & day)

3.7. Production of converted vegetable food

After crops are harvested, transported and temporally stored, they are exported or transformed into vegetable food commodities. In this sub-section yields when converting crops to vegetable food commodities are shown. Data for assumptions were taken from different sources. Wheat yield was taken from FAIM[70], other cereals yields were taken from SAGPyA[71], oil crops yields were assumed from CIARA[72] data, and sugar values were taken from CAA[73]. In Table 14 mayor product yields assumed when converting vegetable food commodities[74] are summarized. Note that main product flows are not always shown in table below; such as is the case of groundnut, which in Argentina is processed and exported mainly as seed.

[69] According to INTA-Pergamino (2006), use of straw is vital for making a soft and thermal nest for breeding sows and for reducing piglet mortality.
[70] FAIM. Statistics: Wheat Production [online]. Available from: http://www.faim.org.ar/prodtrigo.htm [Accessed: 30th September 2006]
[71] SAGPyA (2006). Agriculture estimations [online]. Available from: http://www.sagpya.mecon.gov.ar/ [Accessed: 10th September 2006]
[72] CIARA (2006). Statistics [online]. Available from: http://www.ciaracec.com.ar/ estadistica/index.php [Accessed: 20th September 2006]
[73] CAA (2006). Sugar cane harvest 2003. [online]. Available from: http://www.centroazucarero.com.ar/zafra2003.htm [Accessed: 25th September 2006]
[74] As explained in sub-section 3.1, page 7, production of converted vegetable food is a matching point, since it is necessary to match flows coming from crop production, and products and by-products declared in statistics as produced. Therefore chosen yields may not represent real industry values, but instead matching yields among statistics.

Crop	Raw	Processed	Yield
Wheat	Grain	Straight flour	0.76
Rice	Grain	White rice	0.70
Maize	Grain	Grits, meal & flour	0.55
Sorghum	Grain	Grits, meal & flour	0.88
Sugar	Cane	White sugar	0.33
Sunflower	Achene	Oil	0.45
Groundnut	Pod	Oil	0.33
Soya	Seed	Oil	0.19
Canola	Seed	Oil	0.43
Barley	Grain	Beer	0.51

Table 14. Mayor product yields. All values are expressed on DM basis.

3.8. Distribution and storage

Once main features of animal and vegetable food conversion have been described, it is necessary to understand how the feedstock and feedstuff reach these processes. That is, the connection between the phytomass supplied from fields and the conversion processes we called distribution and storage (D&S).

According to PRECOP (2005), D&S losses are in the range of 6 to 8 % of weight. Physical and quality losses of grains are because of wrong method of storage, incorrect crops drying methods, and infrastructure deficiency in farms, harbors and trucks. In Figure 16 crops D&S losses representation are shown.

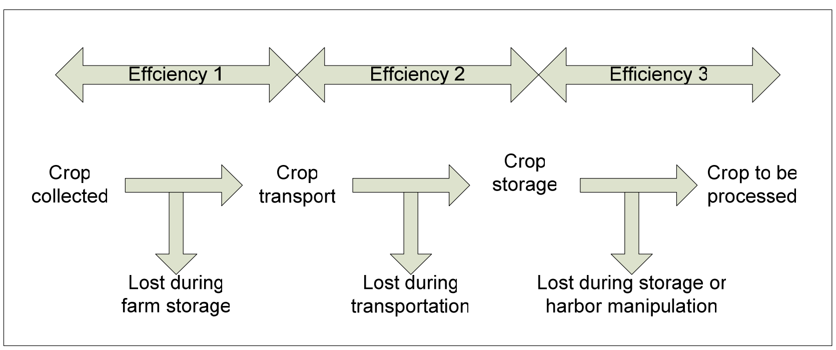

Figure 16. Crops losses from post-harvest to end-use (not to scale).

Considerable losses occur during crops transportation. This is an important activity to considerer and analyze in the agri-food system. According to FAO-SAGPyA (2004), 91% of grains produced are transported by truck, 8% by train and only 1% by barge. For the case of grains transported by truck, Pozzolo et al. (2005) found losses, depending on the humidity of the grains, in a range of 0.4 to 0.9% for the rice crops. Therefore, we can infer that losses occur during transportation at different levels. That is, losses vary between types and humidity of crops, the transport type (train, truck or barge), condition of containers, and traveled distances by crops. Assumption of losses during transportation should be done contemplating all these variables.

Losses also occur when crops are stored. The most important methods used are: N*ormal atmosphere storage*. The most common are silages. Grains are stored dried and the air among them has the same composition as regular air. *Modified atmosphere storage*: the most common storage method used is the plastic bag. This gives oxygen restriction to avoid insects, fungus and grain's oxidation.

Mainly because of infrastructure deficiency, crop losses occur as well when manipulating crops in harbors or in industrial processing plants. Grains and seeds are moved many times until they reach the ship or the processing plant. Broken and damaged grains and increased acidity in soybeans and sunflower seeds during these stages commonly occur [Casini and Brachini, 2005].

There is no local data which quantify D&S losses in a systematic, disaggregated, and global manner. Therefore, data used to assume losses of harvested crops, converted vegetable and animal products and by-products included in FBS were taken from FAOSTAT. However, forage and crop by-products D&S losses were based on own assumptions.

3.9. Production of phytomass

In this sub-section we describe relevant characteristics and assumed values in the model for crops, harvested/conserved forages, and permanent pastures and non-agricultural land. For crops products we detail harvest index, pre and harvest losses, and straw left in field. For pastures products we describe pasture utilization and yields for ruminant sub-systems.

3.9.1. Crop products

It is important to know main features of crop production. That is, composition of harvest index and amounts of crop by-product generated. The most relevant assumptions related to crop production are detailed in this sub-section.

Partition at harvest

Table 15 summarizes assumed values. Crop yields were taken from SAGPyA[75], and if not available from this source were taken from FAOSTAT. Assumptions of harvest index (DM partition) for cereals and oil crops were based on Satorre *et al.* (2003). The groundnut harvest index assumption was suggested by Haro[76], sugar crops harvest index by Ullivarri[77]. Starchy roots were assumed from Wirsenius (2000).

[75] SAGPyA. Agriculture estimations [online]. Available from: http://www.sagpya.mecon.gov.ar/ [Accessed: 10th September 2006]
[76] Ricardo Haro. INTA Manfredi. [Pers. comm. September 2006]
[77] Ullivarri Enrique, Sugar Crops Group, INTA-Famaillá. [Pers. comm. October 2006]

Crop category	Values	Crop category	Values
Wheat		**Soybean**	
Grain yield	2.3	Seed yield	2.7
Harvest index	40%	Harvest index	41%
Straw generated	3.6	Straw generated	3.8
Rice		**Groundnut**	
Grain yield	4.8	Pod yield	2.1
Harvest index	42%	Harvest index	44%
Straw generated	6.6	Straw generated	2.9
Maize		**Sunflower**	
Grain yield	6.0	Achene yield	1.6
Harvest index	55%	Harvest index	31%
Stover generated	5.0	Straw generated	3.6
Sorghum		**Canola**	
Grain yield	4.6	Seed yield	1.3
Harvest index	33%	Harvest index	36%
Stover generated	9.6	Straw generated	2.3
Barley		**Cassava**	
Grain yield	2.0	Tuber yield	3.26
Harvest index	41%	Harvest index	58%
Straw generated	2.9	Phytomass (non tuber) generated	2.4
Sugar cane		**White potato**	
Stem yield	18	Tuber yield	6.3
Harvest index	80%	Harvest index	80%
Tops & leaves generated	4.4	Phytomass (non tuber) generated	1.6
Cotton		**Sweet potato**	
Seed cotton yield	1.3	Tuber yield	1.7
Harvest index	45%	Harvest index	50%
Straw generated	1.5	Phytomass (non tuber) generated	1.7

Table 15. Main crops yield assumptions. Yields are in Mg DM generated per ha. Harvest Index, refers to the proportion of the plant (in DM values) which is grain or seed.

Pre-harvest and harvest losses

Pre-harvest and harvest losses are considerable. There are many restrictions for collection and grain-seeds quality improvements. According to PRECOP[78] (2005) the main reasons for losses are 1) delays in harvest, because of waiting to harvest or scarcity of combine harvester, 2) too high speed harvest, 3) commercial deals between crop producers and harvester companies (payment by surface or weight harvested), and 4) insufficient training of workers who undertake the harvest.

Table 16 summarizes assumed values. For soybeans data was taken from Bragachini and Casini (2005), for maize from Servera (2005), for wheat, sorghum, groundnut and sunflower crops, assumptions were taken from Bragachini and Peiretti (2005). Rice crop data was taken from Pozzolo *et al.* (2005). Assumed values of starchy roots and sugar cane left in field were estimated by the author.

[78] In Argentina 13% of cereal grains produced in the fields, are lost before harvest, due to reasons of physical losses and because of low quality crops. With the aim of reducing these losses by 20%, the National Project to Develop and Spread the Technology to Increase the Efficiency in Harvest and Post harvest and Improve the Cereal and Oil Crops Quality was created in 2004.

Grains left in field		Seeds left in field	
Wheat	3.8%	Soybean	4.4%
Rice	3.3%	Groundnut	9.7%
Maize	5.5%	Sunflower	6.7%
Sorghum	7.0%	Canola	4.7%
Barley	3.8%	**Tubers left in flied**	
Cotton	0%	Cassava	2.0%
Cane stems left in field		White potato	2.0%
Sugar cane	5%	Sweet potato	2.0%

Table 16. Crop losses before and during harvest.

3.9.2. Harvested/conserved forage

With suggestions from Clemente[79] a total supply of 6.5 million DM tons of whole-maize in silage, 28.5 million DM tons of grass-legume[80] species harvested/conserved as hay and silage were assumed. Even though there is big diversity of forage species and conservation techniques, in the model only conservation methods and group-species most commonly used were assumed. To assume losses and harvest index for this feed category were used guidelines from Oscar *et al.*(1997), and therefore before showing the assumptions in the model main characteristics are described.

Grass-legume hay: Factors which influence losses and quality factors in hay forage are a) climate conditions, that is, the moment in which the forage is harvested may affect hay nutrients content, b) collection, values of alfalfa losses during collection are in the rage of 1 to 32% of DM[81], c) storage, tests results showed storage losses variations in the range of 9 to 17% DM basis.

Grass-legume silage: Losses occur in harvested/conserved forage silage during a) collection, because small part of plant are left on the field, b) storage, because air gets in the silage, and therefore the conserved forage oxidizes, and because of c) fermentation losses, which are in the range 3 to 5 % DM basis, and d) rainwater losses, plant nutrient losses are in the range of 1 to 10% DM basis.

Whole-maize silage: Tests showed that for each extra centimeter in the height of harvest of whole-maize, over 15 cm from the ground, 130 [kg DM/ha] are lost, but nutrient quality content is increased. The total DM losses vary considerably for whole-maize silage. Values of 3 to 6% DM losses can be possible in optimal silage condition, but more than 70% of DM could be wasted.

Table 17 summarizes the chosen values of yields and harvest index for the modeled forage categories. It was assumed a harvest index value of 0.9 in DM basis, for whole-maize crops and grass-legume temperate/tropical crop species. Since there is no global data of losses during conversion processes, a medium value of 20% DM basis for all categories were assumed to be lost.

79 Clemente, Gustavo. [Pers. comm. October 2006].
80 In the category grass-legume species maize and soybean are included.
81 Buckmaster (1993) is cited.

Grass-legume hay	
Plant yield [DM ton generated / ha]	4.1
Plant supplied of produced, DM basis	90%
DM loss in treatment	20%
Whole-maize silage	
Whole-crop yield [DM ton generated / ha]	11.1
Plant supplied of produced, DM basis	90%
DM loss in treatment	20%

Table 17. Forage crops yield in Mg DM per ha. Yield is given in above-ground production.

3.9.3. Pasture products

Cropland pastures feed category includes grass-legume temperate/tropical species sown, and later grazed by ruminants. There is substantial structural and functional heterogeneity of cropland pastures. Therefore yields were differentiated by ERs to estimate a national average value. The average value assumed was 11.9 ton DM/ha year. This value was estimated with land use data from CNA02 and cropland yields suggested by Rodriguez[82], as shows Table 31 in the 2nd and 3rd columns.

In addition, the share of tropical/temperate species for cropland pastures as well was estimated with CNA02 data. Weighting cropland values with cattle stock in the country by ER, a share of temperate species of 95.5% of the average cattle diet was assumed.

Permanent pastures include all grassland types where ruminants graze regularly. In the model were assumed two different types. One depicts grassland in Pampeana ER, and the other depicts the rest of grassland in the country. There is immense climatic and geographic diversity of permanent pastures within the country, therefore estimated national average yield was carried out by an ER weighting.

In the appendix, Table 31 shows permanent pasture yields in areas where the beef cattle, sheep, and goat sub-systems are. The 3rd and 4th columns show grazed by ruminants permanent pasture land, as reported by the CNA02. Values shown by ER are based on data from Deregibus (1988), Paruelo *et al.* (1999) and Jacobo *et al.* (2001). The assumed average value for permanent pasture is 2.24 ton DM/ha year[83].

Non-agricultural herbage is the third feed category grazed by ruminants, used in the model. It represents all the phytomass produced in areas which originally are not used for agriculture activities, but because of different reasons ruminants end up grazing the land. Even the amount of this land category is considerable; it was assumed only minor quantities of this land grazed by ruminants. In page 29 was described how much of this feed-type different ruminants sub-systems take as feed.

[82] Rodríguez, Adriana. Cátedra de Forrajicultura. Fac. Agronomía. UBA. [Pers. comm. September 2006]
[83] See discussion of chosen value for average yield, in discussion section, page 74.

Pasture utilization

As explained before, the phytomass yield varies from region to region (see Table 31). Regularly, in regions where the phytomass yield is lower, the pasture utilization is higher. Therefore could be inferred that pasture utilization varies from region to region.

Table 18 shows assumed pasture utilization for each ruminant sub-system. For cattle an average value suggested by Peuser[84], Colombatto[85], and Aello & Di Marco[86] was chosen. Sheep pasture utilization was taken from Lynch *et al.*[87].

Pasture type	Cattle	sheep	Goats
Cropland pasture	0.60	0.60	0.60
Permanent pasture	0.40	0.60	0.60

Table 18. Pasture utilization for each ruminant sub-system, on a dry basis.

3.10. Production and use of by-products and residues

This sub-section describes the main features and assumptions of the biomass by-products and food residues used as animal feed, land conservation, biofuels, and miscellaneous uses.

3.10.1. Crop by-products

Crop by-products are used as industrial fuel, building materials, soil conservation, animal feed and bedding. The use of them as feed through grazing in field is relatively common but not practiced on most harvested land. Cut and carry crop by-products are even less common than grazing. A considerable amount of crop by-products are not used for this purpose because of their low relative value[88].

Crop by-products are used as animal feed when they have competitive handling and transporting costs. Even when crop by-products are unfeasible to be main ingredients in a feed mix, Garciarena (2005) states that they can be used as partial substitute in feed mixes. Their use depend on: a) availability and nutrient composition b) animal category c) price d) possibilities of transportation and storage e) nutrient quality and e) the chance that the by-product will change the taste of the feed mix.

[84] Peuser, Ricardo. Cátedra. de Nutrición Bovina. UNC. [Pers. comm. July 2006]
[85] Colombatto, Dario. Cátedra de Producción de Carne Bovina. UBA. [Pers. comm. August 2006]
[86] Aello, Mario and Di Marco, Oscar. INTA-Balcarce. [Pers. comm. October 2006]
[87] Lynch, Gloria and Simonetti Laura. Cátedra de Ovinos. UNLZ. [Pers. comm. July 2006]
[88] Relative value of a by-product is the price the feed should have if taking the energy and protein value of maize and soybean as a whole-feed. This is the equation farmers use when they decide if a by product is economically feasible to use as feed. If its use is not possible for animal production (as feed or bedding), its potential use is in the chemical industry, land conservation (to maintain humidity and organic matter in land), as building materials, or to produce energy as heat (for boilers), electricity or chemical energy.

We know that crop by-products end up in many possible fates. Figure 17 shows different crop by-products available on fields were analyzed in this study.

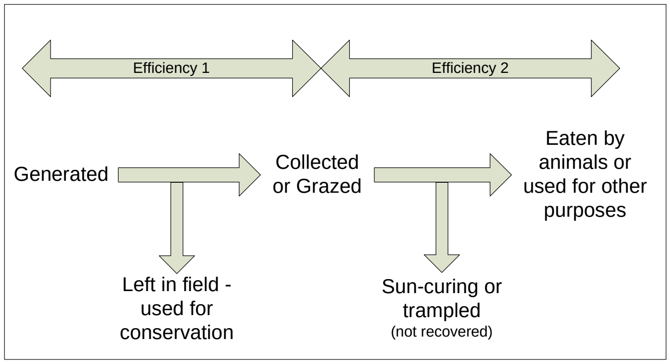

Figure 17. Crop by-products flows (not to scale).

As mentioned on page 28, data assumptions for crop by-products grazed by ruminants were assumed based on CNA02 data. Total surface grazed accounted for 15.6% of total harvested surface, of annual crops for human consumption. Distribution of grazed surface among different crop by-products was according to suggestions from experts, data compilation and personal assumptions. Table 19 shows the share from total available of each crop by-product type assumed to be grazed by ruminants.

Crop by-products		**Crop by-products**	
Wheat straw	10%	Soybean stalk & husks	2.5%
Rice straw	10%	Groundnut stalks	10%
Maize stover	50%	Sunflower stalks & thr. heads	10%
Sorghum stover	50%	Canola stalk & husks	10%
Barley straw	10%	Cassava leaves	10%
Cotton straw	0%	White potato tops	10%
Sugar cane tops and leaves	2%	Sweet potato tops	10%

Table 19. Surface of crop by-products grazed by ruminants.

When ruminants graze is assumed that part of these by-product plants are trampled by animals (not recovered). That is, from the total amount of crop by-products grazed, only 60% end up eaten by animals. The rest is assumed to be trampled and left on the field.

Sugar cane tops & leaves

According to Ullivarri[89], there is no optimal use of by-products in sugar crops areas. In these regions there is a lack of energetic by-products to feed ruminants, and sugar cane tops and leaves do not contribute energy either for proteins feed requirements. Transport is too expensive to move these by-products from harvest to areas where animals could be fed, such as Pampeana ER.

[89] Ullivarri Enrique, Sugar Crops Group, INTA-Famaillá. 2006. [Pers. comm. October 2006]

As well there is a scarcity of protein in animal diets in the region. Therefore these by-products are not valued and there is big volumes left over and burnt on fields. According to Ullivarri, INTA-Famaillá is working on a project to use sugar cane tops & leaves in industry boilers. It seems there are good prospects that these sugar cane by-products will replace soon other energy sources[90].

Cereal straw & stover

Amount of these crop by-products generated is considerable. Cereal straw and stover are used in two different manners to feed animals: 1) direct grazing in field 2) harvested/conserved before use. According to García Burg[91] the first thing to analyze is the energy needed to bring these materials to where they can be used as feed. Therefore regular alternative uses of crop by-products such as bedding, burning and partial incorporation in the soil are practiced.

Why is such an important percentage of straw left in the field? There are many reasons, but basically according to Vicini (2005), a good straw coverage allows better rain water infiltration and less evaporation, and as a consequence giving better water balance for next crop sown. Leaving the crop by-products on the field seems to be the best option most of the time.

In the model, from the total phytomass recovered (not left on land for soil conservation), 90% is considered to be used as animal feed. As well 8% was assumed to be used as animal litter, mainly for poultry but as well for pig, and in minor quantities for ruminants fed in lots. Only 2% was assumed to be used for energy generation. The amount used for energy production, come mainly from the corn cob, when the grain is separated from the rest of the plant in processing plants.

Oil crops by-products

Animal producers ask themselves when taking a decision, how considerably lower will the following crop yield be because of sowing later, if they want to improve the efficiency of the overall phytomass generated[92].

More than 20 years ago [Roquero, 1973] was already mentioning that this by-product was a good option, to feed animals in lots, when milled. Nowadays in some regions soybean are being collected and conserved as hay.

Alternatively, groundnut stalks are also left on the field. Harvester machines take the groundnut pods and leave the stalks on the field. Since these crop by-products have low nutritional content to fed animals, and decomposition

[90] Even though the contribution to the total amount of energy needed is not considerable, it can contribute to diversify the matrix energy source
[91] García Burg. Equidiet Company. [Pers. comm. October 2006]
[92] Soybean is sown after wheat is harvested, and a delayed sowing worsens the humidity available on the soil, and as a consequence the soybean yield.

takes a long time, these by-products are burnt sometimes. However, pigs are sometimes introduced on the fields to eat the uncollected pods[93].

Sunflower straw is an appetizing cereal straw for ruminants. Therefore the graze of it in fields is common. As well it is used as animal bedding and later given to feeder cows flowing out.

Starchy roots tops & leaves

The most relevant starchy root cultivated is the potato, which is located mainly in the south of Buenos Aires province, and in Traslasierras, Córdoba province. The tops and leaves are not tasty for cows. Therefore almost all of the above ground plants are left on the field for soil conservation.

3.10.2. Vegetable conversion by-products

Since grain prices tend to increase continuously, many studies are being done to analyze different combinations of by-products in feed mixes, to achieve good results of daily weight gain in animals. The profits of animal producers can be improved by introducing by-products in animal feed mixes. However many constraints exist with these conversion by-product types, since they have high water content, have to be used in a short period of time, and to be handled and transported with significant costs per unit of nutrient equivalent.

Cereal milling by-products

Generated amounts of these by-products are considerable and most of them are exported. These by-products in the local market are used to feed pets, bovines, sheep and poultry. Note that since no data was available to compare feed animal allocation by animal sub-system, criteria used to assign these by-products were defined in page 27.

By-products generated by processing industries which can not be used as feed are significant as well, i.e. rice hulls are important conversion by-products. Many potential applications have this by-product, such as animal bedding, source of energy in industrial plants, raw material to enhance ceramic and concrete, etc[94].

Estimations of the amount of these by-products generated were based on quantities of products processed and crop composition (parts and different uses of the crop). Data sources used to assume values were FAOSTAT, FAIM[95] and BEN[96]. Of cereal milling by-products available for consumption with the country, 100% were assumed to be used as livestock feed. However, in the case of rice hulls, just 10% of the available amount was estimated to be

[93] Pods uncollected are in the range of 2 to 6 percent.
[94] In Mesopotamia ER its biggest allocation is as broilers bedding (litter).
[95] FAIM Statistics. [online]. Available from: http://www.faim.org.ar [Accessed on 20th September 2006]
[96] BEN is the National Energy Balance, published by the Energy Secretary in November 2006 for the period 1960-2005. In this report are published assumed values of energy production coming from biomass.

used as feed. The rest of this by-product is considered to be used to produce energy mainly in industry boilers.

Oil crops milling by-products

Oil meals are of considerable nutritive value to feed animals. Most of them are exported. However a small percentage is kept for the internal consumption. Data sources used to estimate flows of these by-products were FAOSTAT for international trade and CIARA[97] for assumptions of total production. Note that 100% of oil meals available for the local market were assumed to be used as animal feed.

Groundnuts by-products generated by these industries are of considerable volume. Industry plants which process groundnut have to look for a solution to solve the problem. According to Cantoro[98], nowadays the OLEGA Company mills its residues and generates a matter dust, collected by a cement company, which then uses it in the factory furnace. AGD Company, a vegetable oil producer, uses the groundnut husk as a combustible for the plant's boilers. More useful uses are possible; such is the case of the recent factory built in Cabrera town that make activated carbon from these residues.

Sunflower husk, another considerable by-product generated from milling is of low utilization as animal feed. These by-products are mainly used in industries as an energy source[99], and sometimes as animal feed, for pigs and cattle (to give fibers to the diet), but the amount is negligible compared to the total generated. The husks, was assumed to be zero for animal feed[100], but instead was assumed to be used as energy production.

Sugar crop milling by-products

Cane molasses is used for the production of ethyl alcohol and as energy supplement to animals. The bagasse is used as a combustible, as a natural gas substitute in the sugar industry to produce heat in the boilers, or as a basic raw material for paper production.

According to Ullivarri the sugar crop has improved over the last number of years. Nowadays the main allocation of sugar cane is to produce sugar (white or brown) and secondly alcohol. According to Oliver Muro[101], approximately 90% of molasses is used to produce alcohol, the other 10% being used for yeast production and animal feed[102].

[97] CIARA. [online]. Available from: www.ciaracec.com.ar/ [Accessed on 30th September 2006]
[98] Cantoro, Nicolás. OLEGA Company. [pers. Comm. 30th July 2006]
[99] Such is the case of the cement plant L´Amalí located in Olavarría, Buenos Aires province.
[100] According to ASAGIR (2003), the use of this by-product in the feed mix for breeding cows in periods of low nutritional requirements could be increased.
[101] Oliver Muro, Eduardo. Centro Azucarero Argentino. [Pers. comm. October 2006]
[102] Even not in large amounts, molasses is a choice in some regions as feed for beef cattle. Studies to improve the use as feed are many, i.e. Valy (2000) assess molasses and urea as a complement to use rough forages as feed.

Alcoholic beverages by-products

Of brewers yeast generated, 90% was assumed to be used as feed[103]. Brewers grains and brewers yeast (dried or wet) are generated when producing beer. The success of using these by-products in different cattle categories depends on competitive cost, nutritive quality and the category of animal to feed. In the model estimated generation of these by-products is bigger than in reality, since all alcoholic beverages were depicted using the category beer-equivalent.

Food industry by-products

The vegetable-fruit industry generates residues when making classification of raw material, packaging, and producing juice. The amount generated is not big, compared to other by-products, and the transport and handling are expensive, because of its high water content[104].

By-products generated from production of candies, sweets, and bakery by products such as bread, cookies, cakes, dough, etc, are generated in considerable amounts. Potato processing plants which make frozen and ready to cook potatoes specialties also generate considerable amounts of these by-products.

These by-products are used to feed cattle and pigs in lots. However they were not included as a feed choice in the model. Instead the category “food waste” described in page 46 represents all these feed-type used as animal feed.

3.10.3. Animal conversion by-products

The model included flows of fifth quarters only. However other existing by-products, such as dairy by-products, animal manures and used litter are mentioned in this sub-section[105].

Dairy by-products

Considering that 42.5% of total fresh milk generated in the year 2003 was used to produce soft, semi-soft and hard cheeses, more than 20% of total milk solids ended up as cheese whey, which is equivalent to 210 Gg of solids in whey. According to the CIL[106] liquid whey was powdered, obtaining 10.8 Gg DM. However this value is the equivalent of near 5% of the total by-product generated in this industry. Even considering a large amount of it coming back to the dairy industry to be re-processed or to make ricotta, a big share of whey may be used for animal feed in a liquid state. However in the model was assumed no use of this particular animal by-product as feed.

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[103] The value of brewer yeast used as feed, is own assumption not based on any data.
[104] Hofer *et al.* (1991) analyzes its potential use, and shows that citrus pulp can be a good choice for early weaned calves, since it has similar nutrition properties to forages when dried.
[105] The use of this by-product as animal feed was probably underestimated.
[106] CIL - Centro de la Industria Lechera (2006). Rates and Statistics [online]. Available from: http://www.cil.org.ar/ [Accessed on 10th October 2006]

Animals fifth quarter

Fifth quarters are used in different industrial processes, such as chemical, food, pharmaceutical and animal nutrition industries. Multiple fifth quarter-types by animal sub-system, were depicted in the model by a group for each animal sub-system. It was assumed that 40% from the total generated amount was used to feed animals.

Some animal meat producers, use chicken fifth quarter as supplement in animal diets. Feather, head, feet, intestine, abdominal fat, red offal, gizzard and blood are processed to obtain raw materials of high biological value for feeding pets and fishes, and to some extent to feed meat-type animals[107]. The by-products obtained are chicken meals, meals from incubator plants, feather meals, chicken oil, red offal meals, blood meals and dried livers.

Slaughterhouses generate considerable amounts of cattle carcass by-products. Most of these by-products are sold to companies which process them to obtain products for human consumption, animal feed, and other uses. For example, *Refinerías del Centro Company* produces edible animal fats, buttering, emulsions, and bone meals with these by-products. *Yeruvá Company*, in Santa Fe province, makes whole-blood, plasma and hemoglobin concentrated, and dust for blood sausage or pudding.

Other animals fifth quarter such as sheep and goats, have different uses and final allocations if they are culled in official slaughterhouses or in family houses. The total amount generated is very small compared to cattle and poultry. Therefore the allocation of them as animal feed was identical to all animal sub-systems fifth quarters.

Animal manures and used litter

Chicken used litter is a by-product generated in considerable amounts in some regions. This type of by-product is considered by animal producers as an option to feed cattle. According to Jaurena and Canelón (2006) these by-products are of low nutritional value. However used litter made of sunflower straw is the most desirable in ruminants. Its use is feasible in high proportion for feeder cows flowing out of the system[108]. In the model was assumed no use of this particular animal by-product as feed.

Ruminant manure is the biggest animal by-product in terms of mass. However most of animal sub-systems which generate it are located in open fields. That is, cattle, sheep, and goats are reared in extensive manner, in open fields. Therefore, manure stays on field contributing with most nutrients soil cycling. Based on same assumptions from BEN, in the model 1% for cattle and sheep and 0.5% for the pig sub-system generation was assumed to be recovered to be used for energy production.

[107] It is officially forbidden to use these by-products as feed for ruminants.
[108] INTA-C. del Uruguay has made several tests to asses the feasibility of using chicken litter as a substitute for grain.

System-external input

In this sub-section we describe and quantify the values chosen for the system-external inputs considered in the model, such as by-products coming from cotton seed and fish meal coming from processed fish.

Cotton seed

Assumed values for cotton yarn, cotton meal and cotton seed oil, were based on FAOSTAT[109] data. In the model by-products from these crops were only assigned to feed monogastric animals. However according to Balbuena & Kucseva (2002) the whole cotton seed is an abundant and low cost resource to feed ruminants in Mesopotamia ER, and constitute a competitive energy and protein source for beef cattle to complement when pasturing.

The model assigned the total production of lint to yarn production. 66% of cotton seed was assumed to be used for oil production. The rest of the seeds were considered to be cotton seed waste. However this may not be the case since beef cattle are supplemented with this by-product when they graze in field in Mesopotamia ER.

Fish meals

Considerable amounts of fish are processed. However the recovery rates of by-products are low. Assumptions of fish meal production and use as animal feed within the country were based on guideline values suggested by Rodriguez[110]. Around 2 and 1.8 thousand tons of fish meal and fish oil respectively were consumed as animal feed. However the model assumed a total consumption of 2 thousand tons of fish meal as animal feed only.

Animal diets which include these by-products are pigs and poultry. In the case of pig feed mix, 15% of protein supplement is based on fish meal, giving a total consumption of 1.5 Gg of DM. In the case of broiler diets, 0.5% of fish meal in the total supplement protein was assumed, giving a total consumption of 0.5 Gg DM fish meal.

3.10.4. Food residues

Food residue is defined as the difference between food at the processing plant gate (or end-use) and food eaten (or intake). This category of by-products includes all food produced and finally not eaten by people. These are food wastes in households, institutions, food shops, and restaurants when storing, preparing and serving food. This residue is included as animal feed in the model. However recovery rates are not known.

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[109] During the year 2003 only 158,000 ha were sown. The lower production and higher demand made the country a net importer of cotton yarn. However this is not the regular situation of this important raw material. It is regularly produced and exported in considerable amounts. As a consequence of this particular situation, fewer by-products were available to feed animals.

[110] Karina Rodríguez. Moliendas del Sur Company. [pers. comm. 15th October 2006]

Even if residues are used to feed ruminants, pigs, and poultry; the model considered only pigs were fed with this feed category. Recovery rate or re-use (to fed pigs) was assumed to be 0.5% of the total generated. This represents a share in the pig total feed mix of slightly over 2%.

4. Results

In this section we present the results obtained. For a correct interpretation of them it is important to be acquainted with the model value assumptions. The results are shown in three different sections. In the first one, the main characteristics of the biomass flows in the agri-food system are shown. In the second one, results regarding different animal sub-systems are shown. In the third section, results of generation and allocation of by-products and food residues are shown.

4.1. The whole system

An overview of the entire system is necessary for an overall comprehension of the generation, flows and fates of the biomass. Therefore in this sub-section we show and describe results of main features of the whole system. On page 82 land appropriation model results with CNA02 and FAOSTAT data sources are compared.

4.1.1. Phytomass appropriation to produce food

This sub-section includes a table with the estimated biomass flow balance for the agri-food system (see Table 20). Figure 18 shows the condensed picture of estimated flows, of the food-induced terrestrial phytomass.

In this figure some small flows are not shown. In addition, since almost all crop by-products are given to animals without prior treatment (crop by-products are grazed in field after harvest), no losses of crop by-product treatments were accounted for. Animal manures fates were not analyzed, since more detailed information is needed to model these flows.

Note that crop by-products “not used in the agri-food system” are mainly phytomass used as energy. However other uses are included here such as crop by-products used to feed animals out of the agri-food system. These by-products may be used for purposes other than feeding animals of the system or not even used for any specific purpose. Therefore a more detailed analysis of crop by-products allocation is needed to map their use or fate better.

Processed vegetable by-products “not used in the agri-food system” depict flows as molasses used to produce alcohol, bagasse to produce paper and heat; sunflower husks burnt in industry plants, etc, and amounted to 111 PJ. Fates to feed animals amounted to 42 PJ, a substantial amount, but when compared with total feed use is still not significant.

Note that permanent pasture use value corresponds to land effectively grazed by ruminants, which means that assumed value does not match with the existing total amount of pasture in farms.

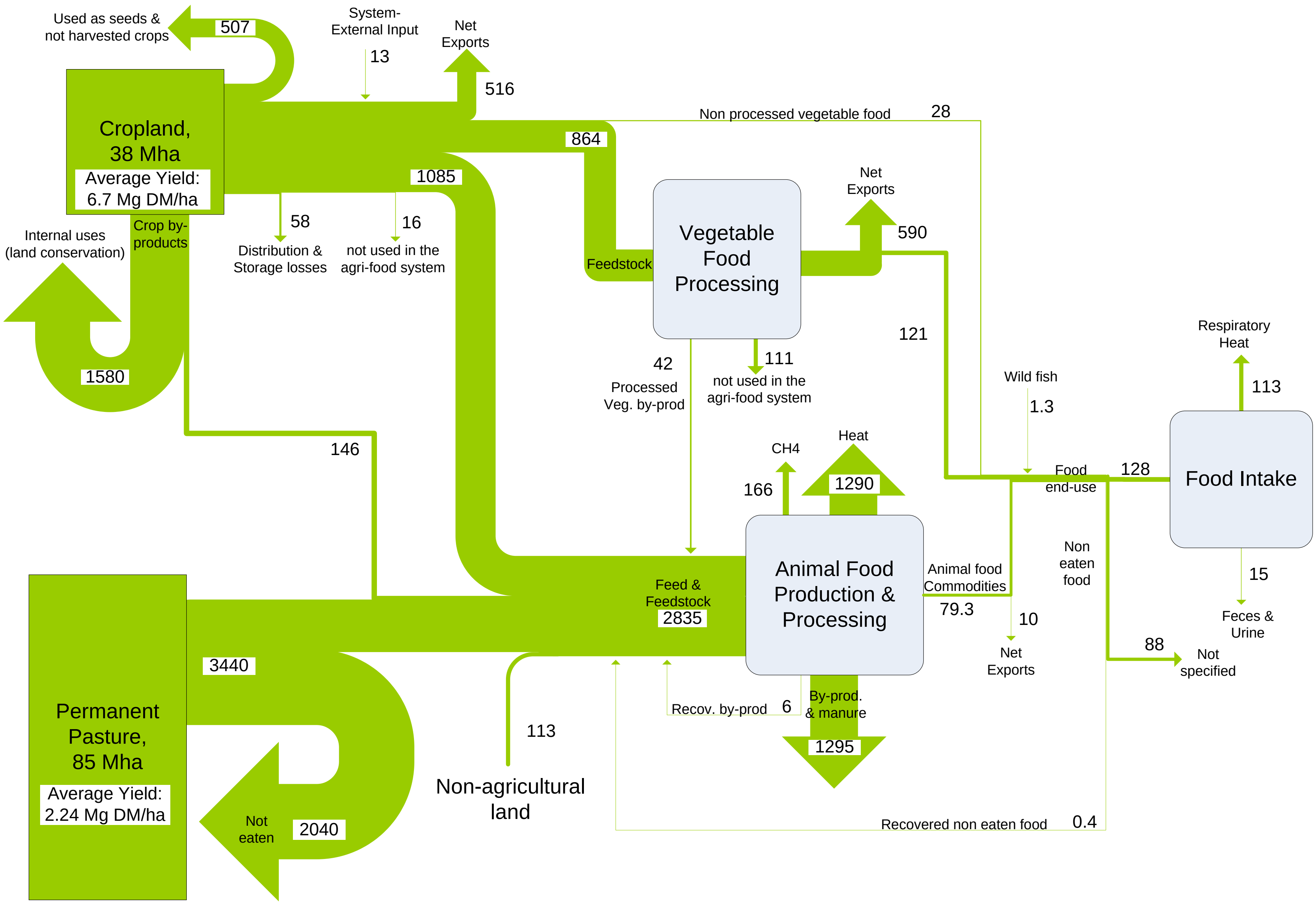

Figure 18. Land use and biomass flows in the Argentinean agri-food system during the year 2003. Values are expressed in PJ GE (HHV)/year.

	SUPPLY					DISTRIBUTION				USE IN FOOD SYSTEM											
	Generated			Left on field		Net-imported		Lost & damaged		Used as feedstock for vegetable products		Used as feed & feedstock for animal products		Used as litter for animal bedding		Used as food		Actually eaten		No use within the food system specified	
	As-is weight (Gg)	Dry weight (Gg)	GE (HHV) (PJ)	GE (HHV) (PJ)	Share of Generated	GE (HHV) (PJ)	Share of Generated	GE (HHV) (PJ)	Share of Generated	GE (HHV) (PJ)	Share of Generated	GE (HHV) (PJ)	Share of Generated	GE (HHV) (PJ)	Share of Generated	GE (HHV) (PJ)	Share of Generated	GE (HHV) (PJ)	Share of Generated	GE (HHV) (PJ)	Share of Generated
SUM ALL FLOWS	1 932 008	591 017	11 002	5 551	50%	-1 119	-10%	62	0,6%	832	8%	2 875	26%	10	0,1%	216	2,0%	128	1,2%	336	3,1%
FOOD-TYPE FLOWS	*1 930 359*	*590 135*	*10 985*	*5 546*	*50%*	*-1 116*	*-10%*	*62*	*0,6%*	*832*	*8%*	*2 874*	*26%*	*10*	*0,1%*	*213*	*1,9%*	*127*	*1,2%*	*331*	*3,0%*
All phytomass	1 156 009	461 738	8 554	4 263	50%	-516	-6%	58	0,7%	832	10%	2 826	33%	10	0,1%	28	0,3%	12	0,1%	21	0,2%
Edible-type crops	**107 211**	**77 139**	**1 633**	**123**	**7,5%**	**-516**	**-32%**	**26**	**2%**	**832**	**51%**	**92**	**6%**			**28**	**1,7%**	**12**	**0,7%**	**16**	**1,0%**
Cereal grains	35 835	31 345	583	38	6,4%	-313	-54%	15	2,6%	124	21%	78	13%							16	2,7%
Starchy root tubers	2 474	537	9,3	0,4	4,7%	-0,5	-5,0%	0,9	10%			0,5	5%			6,9	74%	4,1	44%	0,1	1,5%
Sugar crops stems & roots	18 907	6 050	103	7,2	7,0%			0,2	0,2%	95	93%										
Oil crops seeds, pods, ach. & fruits	41 542	37 410	907	78	8,6%	-194	-21%	8,3	0,9%	613	68%	13	1,5%								
Other edible-type cultivation-prod.	8 454	1 796	31			-8,5	-27%	1,5	4,9%							21	68%	7,8	25%		
Animal forage crops	**163 514**	**38 859**	**699**	**70**	**10%**			**16**	**2,2%**			**614**	**88%**								
Grass-legume	134 603	31 632	569	57	10%			13	2,3%			500	88%								
Whole-cereals	28 911	7 228	130	13	10%			2,9	2,3%			114	88%								
Grazing products	**772 638**	**249 060**	**4 483**	**2 494**	**56%**							**1 989**	**44%**								
Cropland pasture	185 768	43 656	786	314	40%							471	60%								
Perm. pasture & browse	546 487	191 271	3 443	2 039	59%							1 404	41%								
Herbage from non-agricultural land	40 383	14 134	254	141	55%							113	45%								
Edible-type crops by-products	**112 645**	**96 680**	**1 738**	**1 576**	**91%**			**16**	**0,9%**			**131**	**7,6%**	**10**	**0,6%**					**4,7**	**0,3%**
Cereal straw & stover	44 275	38 737	696	556	80%			14	2,0%			114	16%	10	1,4%					2,7	0,4%
Starchy roots tops	854	171	2,9	2,8	99%			0,0	0,1%			0,0	0,5%							0,0	0,2%
Sugar crops tops & leaves	3 559	1 513	26	26,2	99%			0,0	0,1%			0,2	0,9%								
Oil crops by-products	63 957	56 259	1 013	991	98%			2,1	0,2%			17	1,7%							2,0	0,2%
All convers. pr. and by-pr.	741 335	123 042	2 327	1 180	51%	-600	-26%	4,5	0,2%	0,0	0,0%	48	2,1%	0,0	0%	184	7,9%	115	4,9%	310	13%
Edible-type vegetable products	**17 520**	**12 332**	**344**			**-223**	**-65%**	**0,0**	**0,0%**							**120**	**35%**	**78**	**23%**	**0,8**	**0,2%**
Cereal products	4 975	4 295	78			-9,3	-12%									69	88%	45	58%		
Sweeteners	1 857	1 857	32			-6,8	-21%									26	79%	17	52%		
Vegetable oils	5 734	5 734	225			-207	-92%									18	7,9%	11	4,7%	0,8	0,3%
Other vegetable products	4 954	446	7,8			-0,6	-7%	0,0	0,4%							7,2	92%	5,5	70%		
Animal products	**12 179**	**2 637**	**68**			**-8,3**	**-12%**	**4,5**	**6,6%**							**55**	**81%**	**30**	**44,3%**		
Carcass	3 707	1 548	41			-4,6	-11%									36	89%	19	46%		
Cattle whole milk	8 195	1 000	25			-3,7	-15%	4,4	17%							17	68%	10	40%		
Chicken eggs	277	89	1,8				-0,5%	0,1	5,4%							1,7	94%	1,2	65%		
Vegetable conversion-by-prod.	**31 227**	**24 748**	**520**			**-367**	**-71%**					**42**	**8,1%**			**0,6**	**0,1%**	**0,4**	**0,1%**	**110**	**21%**
Cereal milling by-products	1 790	1 564	30			-5,4	-18%					23	76%			0,5	2%	0,3	1,1%	1,1	3,6%
Sugar crops conversion by-prod.	6 777	3 466	98									0,4	0,4%							97	100%
Oilseed conversion by-products	21 858	19 466	388			-362	-93%					16	4,0%							10	2,6%
By-prod. from other veg. conv.-prod	801	252	4,9									3,6	74%							1,3	26%
Animal conversion-by-prod.	**680 409**	**83 324**	**1 395**	**1 180**	**85%**	**-1,7**	**-0,1%**					**5,8**	**0,4%**			**8,5**	**0,6%**	**6,4**	**0,5%**	**200**	**14%**
Carcass by-products	2 733	639	17			-1,7	-10%					5,8	34%			8,5	50%	6,4	38%	0,9	5,4%
Faeces, urine & used litter	674 700	79 710	1 213	1 180	97%															33	2,7%
Methane	2 976	2 976	166																	166	100%
All residues	33 015	5 354	104	103	100%	0,0	0%	0,0	0,0%	0,0	0,0%	0,3	0,3%	0,0	0%	0,0	0%	0,0	0%	0,0	0%
Non-eaten food	14 055	4 216	89	88	100%							0,3	0,4%								
Faeces & urine	18 961	1 138	15	15	100%																
OTHER FLOWS	*1 649*	*883*	*17*	*5,2*	*30%*	*-2,8*	*-16%*					*0,3*	*1,8%*			*3,7*	*21%*	*1,0*	*5,7%*	*5,2*	*30%*
Aquatic-related food flows	**918**	**236**	**4,7**			**-3,4**	**-72%**					**0,04**	**0,8%**			**1,3**	**27%**	**0,7**	**15%**		
Materials-related flows	**731**	**647**	**12**	**5,2**	**42%**	**0,6**	**4,6%**	**0,0**	**0,0%**			**0,3**	**2,1%**			**2,4**	**19%**	**0,2**	**2%**	**5,2**	**42%**

Table 20. Summary of Argentinean Biomass flow balance of the agri-food system. Year 2003.

4.1.2. Relative importance of different biomass categories

Phytomass appropriation[111] is defined as "the total phytomass production induced by the use of the agri-food system". It refers to the sum of phytomass used and all other parts of the plant matter production above-ground, except for roots and tubers for which whole plant production is included. Wirsenius (2003, p. 223) explains the division of total phytomass production as phytomass "products" (e.g. cereal grains or eaten pasture), and phytomass "by-products" (e.g. cereal straw) or "non-used" phytomass (e.g. non eaten pasture).

Figure 19 shows the phytomass appropriation by major phytomass categories[112]. In weight terms, the total phytomass appropriated for **animal feed** products was: permanent pasture 191 Tg DM, cropland pasture 43 Tg DM, whole-cereals 7 Tg DM, other animal forage crops 32 Tg DM and herbage from non-agricultural land 14 Tg DM. For **human food** consumption: cereals 70 Tg DM and other edible-type crops 104 Tg DM[113].

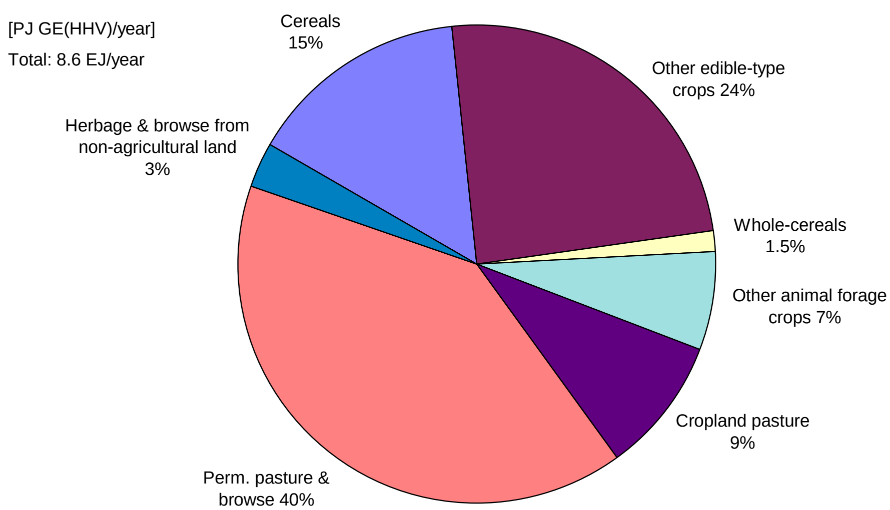

Figure 19. Total phytomass appropriation in the agri-food system.

[111] According to Troell *et al.* (2004), the methodological appropriateness of allocating a zero biophysical cost for by-products is debatable. It can be argued that treating the energy costs associated with making a given by-product available as free, simply because they are designated as ''wastes,'' is arbitrary and potentially misleading. Troell et *al.* (2004) alternatively propose that for some products the energy costs could be based on the proportion to the relative weights of product and byproduct. And a third possible accounting convention might be based on the relative prices of by-products. The last approach only works, however, if a market for the by-product exists, or if alternatives to the byproduct exist, from which an opportunity cost could be estimated.

[112] The category "other edible-types crops" includes all edible-type crops other than cereals, and the category "other animal crops" includes all animal forage crops other than whole-cereals.

[113] Taking into account the degree of uncertainty, global values were rounded to whole numbers.

4.1.3. Trade influence

In order to know how trade influences the total phytomass appropriation we use the concept defined by Wirsenius (2000, pp. 113) of **Trade-neutral phytomass appropriation**, as the required phytomass if all food end-use was met entirely from production within the country (excluding imports-exports).

Thus, here we want to know how much the phytomass appropriation would be if international trade was excluded. This means that if a product is exported, demanded by a second agri-food system (another country), all phytomass appropriation induced by such products are excluded from estimations. Looking at the concept another way, if a product is imported the trade-neutral phytomass appropriation is calculated as if that product was produced in the country with the efficiencies.

Since exports of converted vegetables and animal feed commodities are significant in relation to their total production, trade-neutral phytomass appropriation would differ significantly from those in Figure 18.

Figure 18 shows that most of the phytomass appropriation resulted from food consumed within the country. The difference between marginal (8.6 EJ) and neutral-trade (5.2 EJ) phytomass appropriation is only of 40%. This means that most of the phytomass appropriated is to produce food consumed within the country boundaries[114].

Obviously there are some products which are exported in bigger amounts, and therefore have bigger influence when estimating the trade-neutral phytomass appropriation. That is the case for vegetable oils, cereals products, and cattle beef, which make the biggest difference between actual and neutral-trade appropriation.

Figure 20 shows summarized flows, if no international trade of any product and by-product existed, that is no by-products were considered to be exported either. Note that crop by-products and vegetable food processing by-products used as animal feed, were assumed to keep the same shares of total generation than those shown in actual biomass flows in Figure 18.

That is, phytomass appropriated by animals consumed within the country is over 56% of the total terrestrial phytomass within the agricultural system, and 90% of the phytomass appropriated to produce food products which were consumed within the country boundaries.

[114] What would it happen If a diet based on more crop-type products is implemented? How many people could be fed with that amount of crops?

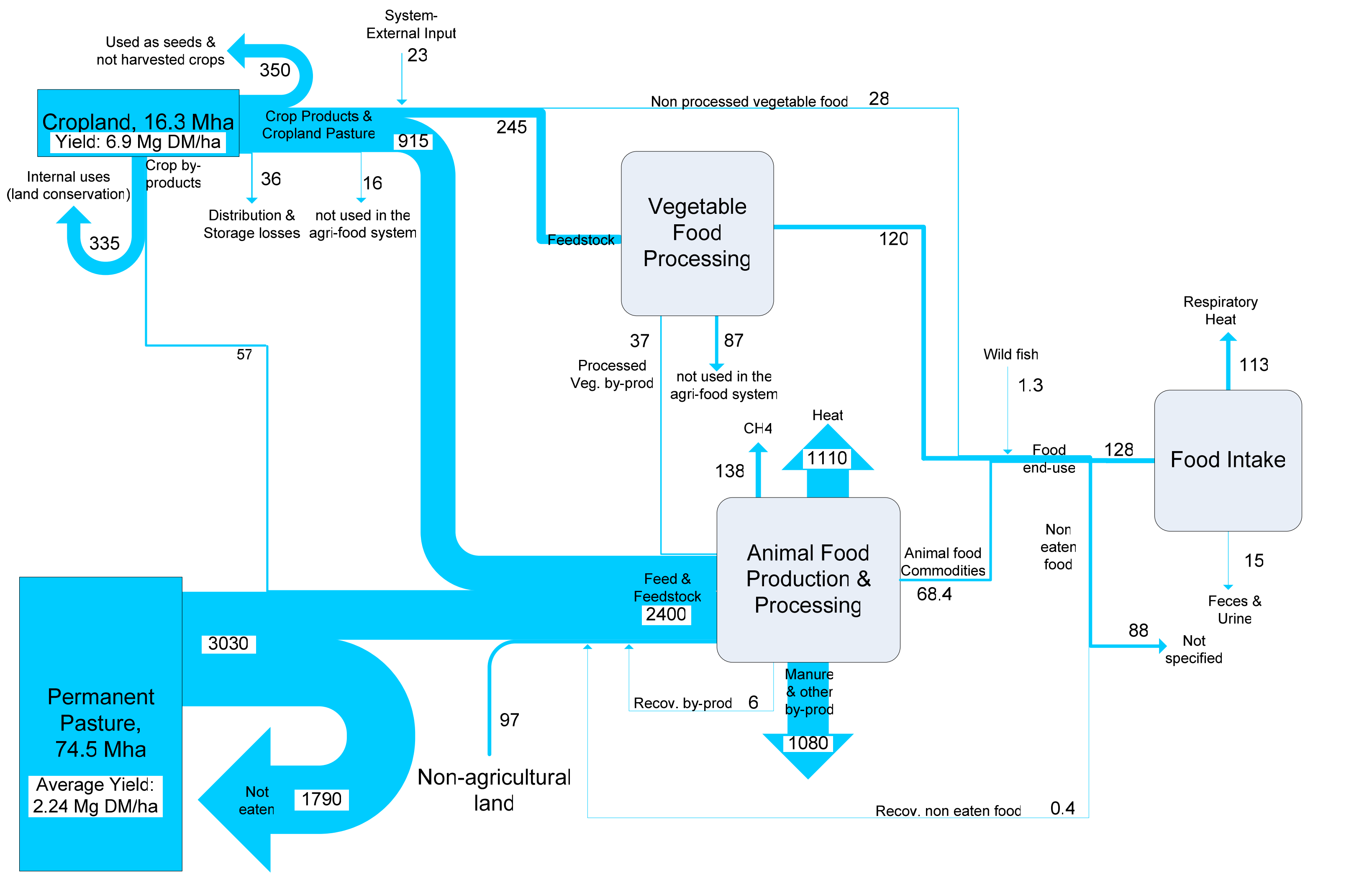

Figure 20. Land use and biomass flows during the year 2003, if no international commerce existed. Values are expressed in PJ GE (HHV)/year

4.1.4. Phytomass fates

Fates of appropriated phytomass as food eaten and other fates[115] are described in sub-section 4.3.4. As Figure 21 shows, almost half of the biomass turnover stayed on the field. More specifically pastures not eaten represent 26% (2.2 EJ), and phytomass used internally, mainly seeds and straw used for soil conservation, represent 24% (2 EJ) of the total generated.

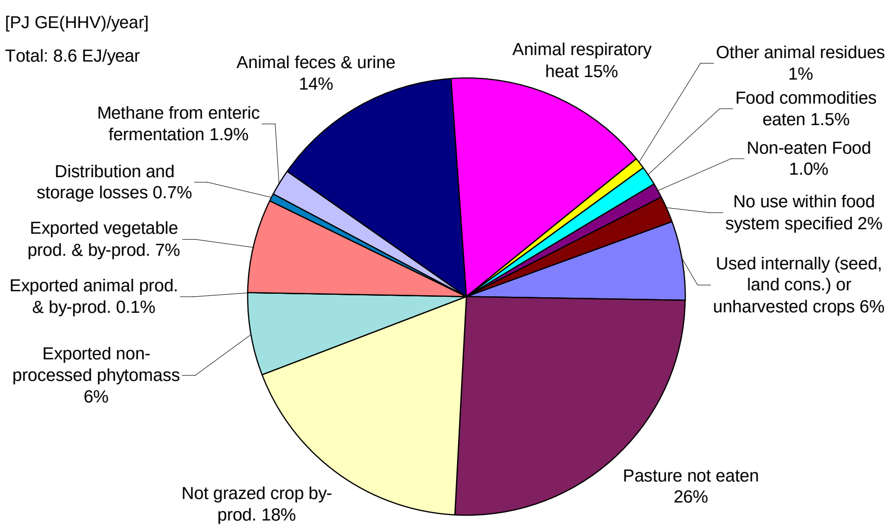

Figure 21. Fates of appropriated phytomass in the Argentinean agri-food system. Values are expressed as the share of the total amount of appropriated phytomass.

Astonishing, this figure shows the share of total appropriated phytomass which ends up as eaten food, as only 1.5%. Other relevant flows shown in Figure 21 includes animal manure which accounted for 14% (1.2 EJ), animal respiratory heat with 15% (1.3 EJ), and methane from enteric fermentation with 2% (167 PJ) of total phytomass appropriation.

4.1.5. System efficiencies

It is necessary to use aggregated efficiency measurements to know the system efficiencies. Therefore we use the concepts developed by Wirsenius (2000, p. 115) here:

Overall efficiency = food intake (excluding the system-external inputs) / appropriated phytomass.
Feed & feedstock utilization efficiency = [feed intake (for animal commodities) + feedstock use (for processed vegetable commodities)] / appropriated phytomass.
Conversion efficiency = products generated / [feed intake (animal commodities) + feedstock use (processed vegetable commodities)].
Commodities utilization efficiency = food eaten / food products generated.

[115] Wirsenius mentions in his thesis that all “fates” are mainly a consequence of the system-boundaries – eventually almost all of the phytomass will be transformed into CO_2 and heat.

Note that the product of the last three concepts gives the overall efficiency. Figure 22 shows (not to scale) how these efficiency concepts relate to the transformations of flows in the system.

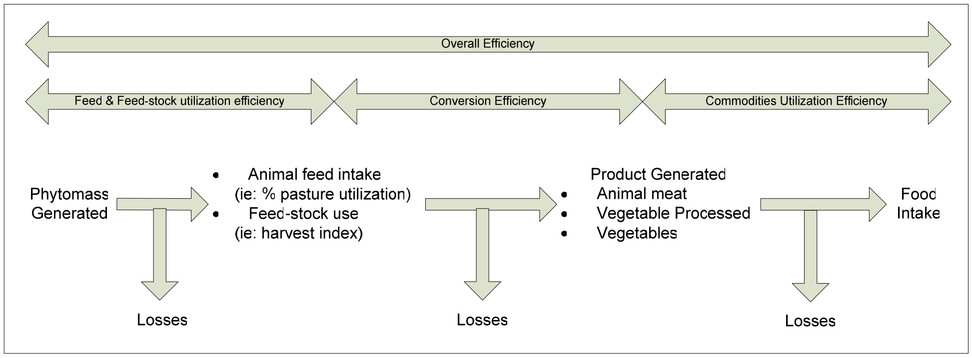

Figure 22. Efficiencies of the food-system (not to scale).

Figure 23 shows a comparison of the efficiencies for the aggregate of all vegetables and animal food commodities. From this figure the reader can deduce which and where the most important losses of the overall food chain occur[116]. This figure highlights the large differences in overall and conversion efficiency between vegetables and animal products. Instead the 2.4% "overall efficiency" of the agri-food system gives the average efficiency for all commodities including net import/exports.

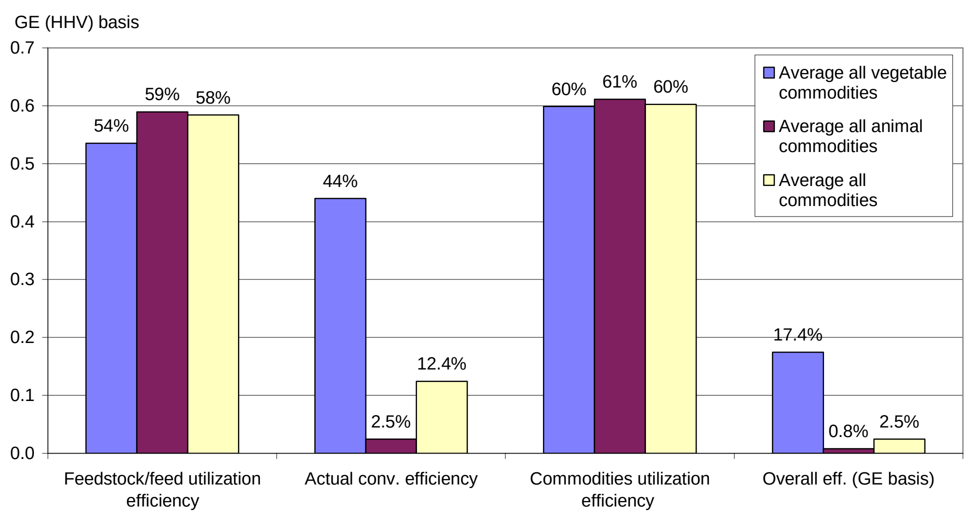

Figure 23. Efficiencies for the three principal parts of the agri-food system. Average by commodity-groups. Trade-neutral values.

Figure 24 shows where the largest losses occur differentiated by sub-systems, following the concepts previously defined. Overall efficiencies are shown for each sub-system and for the average whole agri-food system with a value of 2.5%. From the figure can be appreciated the considerable different in overall efficiencies among sub-systems; as might have been expected starchy roots have by far the highest overall efficiency, followed by cereals,

[116] Note that values are expressed on GE (HHV) basis. Therefore, these efficiencies should not be compared with typical conversion efficiencies expressed on as-is weight basis.

sweeteners, vegetable oils, and other vegetables. In contrast animal products have by far the lowest overall efficiencies.

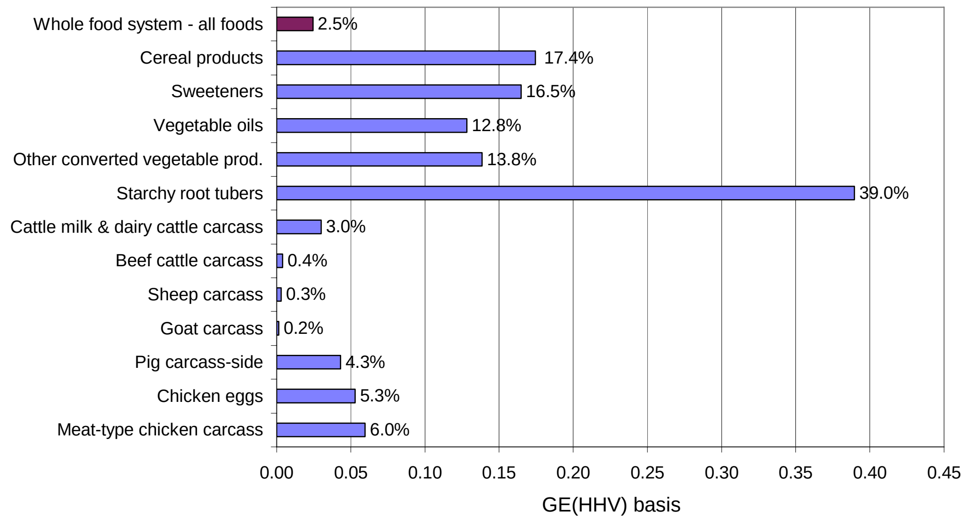

Figure 24. Overall efficiency for separate sub-systems.

The following three figures, from Figure 25 to Figure **27**, illustrate the three efficiencies in a disaggregated manner for each food sub-system. As can be appreciated, conversion efficiencies tend to be much lower for animal food sub-systems compared to vegetables sub-systems. In contrast commodities utilization is higher for the former.

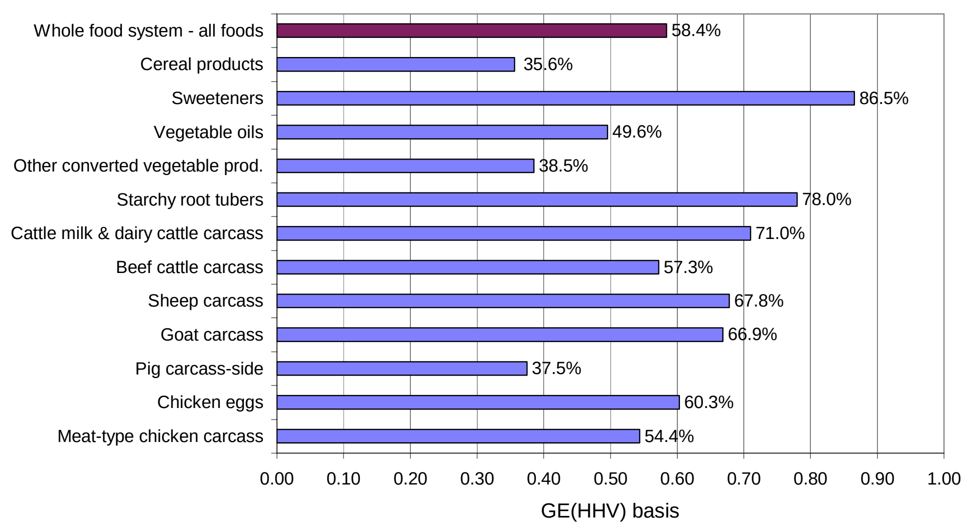

Figure 25. Feed and Feedstock utilization efficiency for separate sub-systems.

Low “conversion efficiencies” for all products demonstrates that the largest losses generally occur at this stage of the food chain. However, for cereals, oil crops and “other converted vegetable products, the feedstock efficiency was also rather low, mainly due to low usage of their crop by-products and relatively low harvest index of these crops. Note that the conversion efficiency of “other non-converted vegetable products” such as fruits, species, etc is equal to one, since these phytomass products are essentially ready to be used for human consumption after harvest.

Note that the cattle milk sub-system has the particularity of showing the average of the efficiency of “cattle milk & dairy cow carcass” and “dairy cattle bullock, steer & heifer carcass”. If considering the efficiency of the cattle milk & dairy cow carcass alone, the overall efficiency was 3.6% with efficiencies of 71%, 12.1%, and 48% respectively.

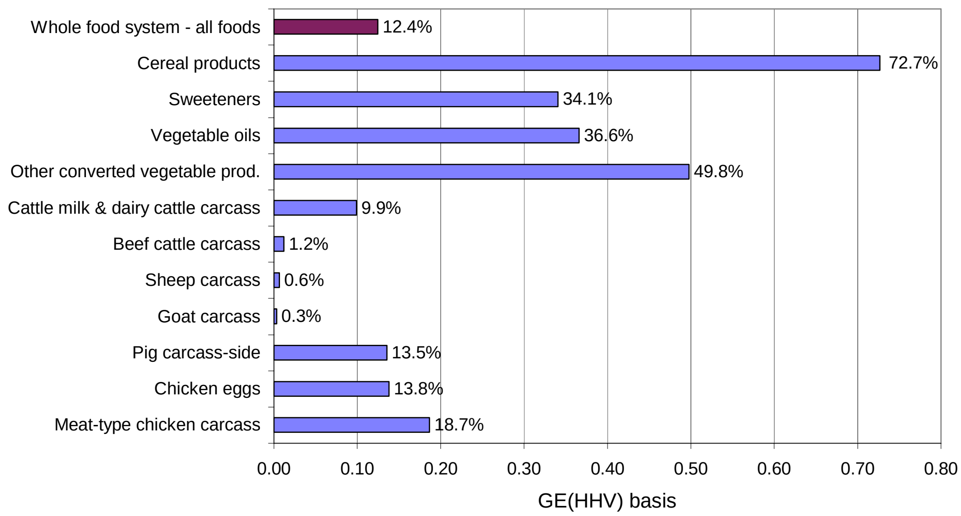

Figure 26. Conversion efficiency for separate sub-systems.

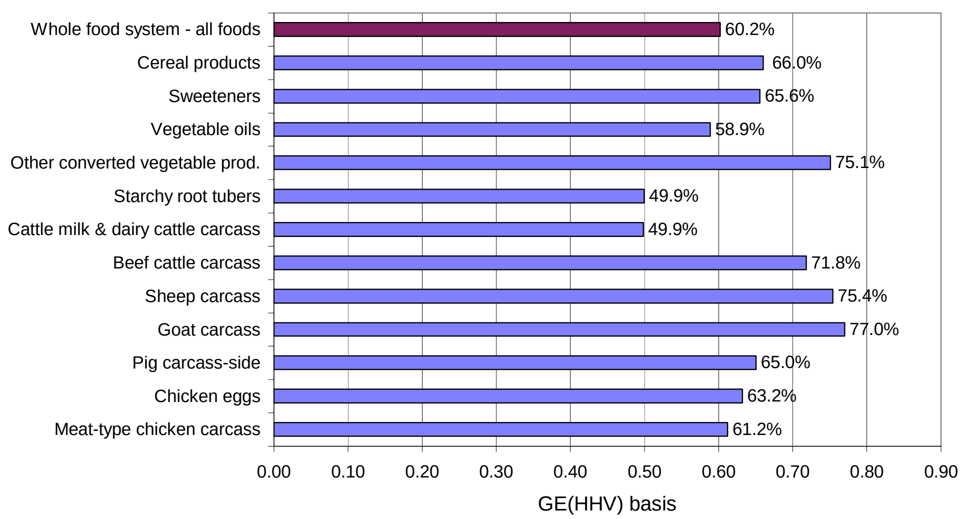

Figure 27. Commodities utilization efficiency for separate sub-systems.

4.1.6. Relation between food intake and phytomass appropriation

A comparison between phytomass appropriation and the corresponding vegetable and animal food intake[117] is shown in Figure 28. It is clear how large the phytomass appropriation is for producing such a small quantity of animal carcass, milk, eggs and other animal food products.

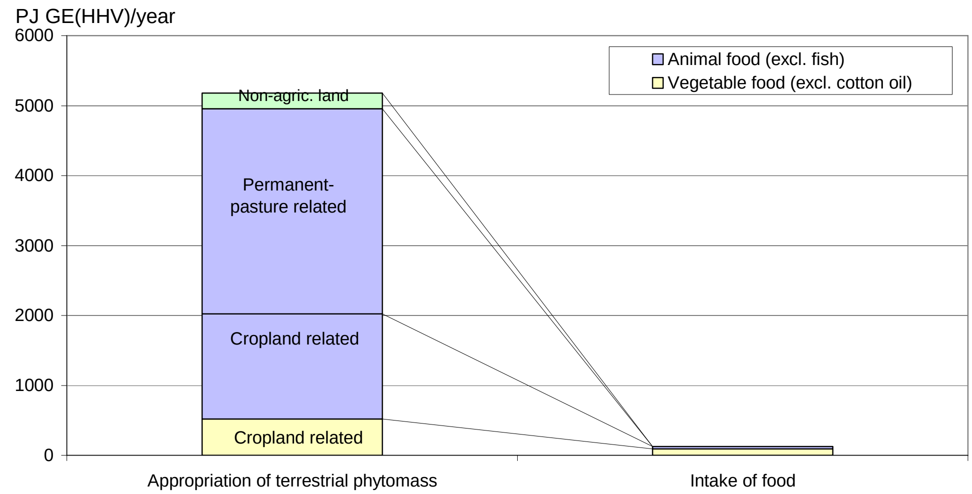

Figure 28. Intake of vegetable and animal food, and corresponding appropriation of cropland and permanent pasture phytomass for vegetable and animal food.

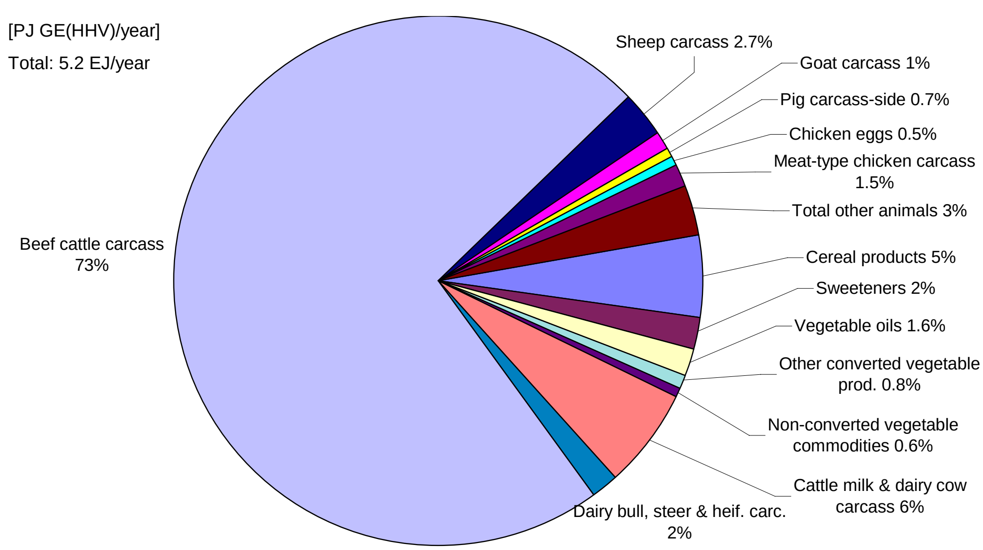

Figure 29. Phytomass appropriation related to separate sub-systems. Trade-neutral.

Figure 29 shows the phytomass appropriation caused by domestic consumption. That is neutral-trade phytomass appropriation divided by major food sub-systems. Again, phytomass appropriation induced by beef cattle carcass dominates with more than 74% of total. Sheep and milk cattle

[117] Wirsenius mentions that phytomass appropriation for animal food includes no more than the phytomass appropriation induced by the feed use of phytomass products. Thus, it does not include, for example, the use of crop by products originated from production of vegetable food commodities.

products are considerable as well with 3.4% and 6% of the total appropriation. In contrast, cereal products which contribute considerably to the dietary energy intake for an average person, appropriates a mere 5% of the total phytomass.

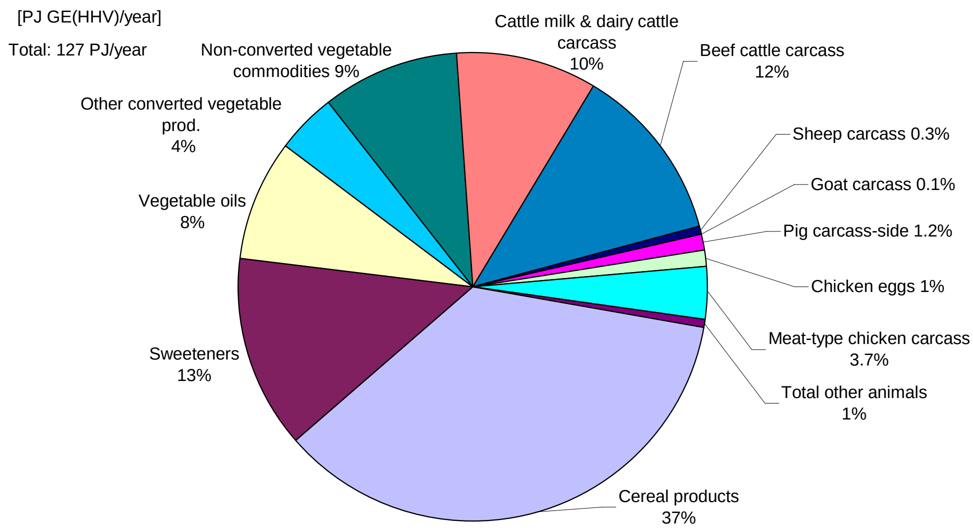

Figure 30. Food intake related to separate sub-systems. Trade-neutral.

Food intake divided on major food products is shown in Figure 30. To contrast Figure 31 shows a direct comparison food intake and its phytomass appropriation for separate sub-systems. It is notable that while cereals crops demanded no more than 5% of the total phytomass they contributed to almost 36% of diet [both numbers on GE (HHV) terms]. In stark contrast, beef cattle carcass contributed to 12.7% of diet, but instead appropriated 71.3% of the phytomass. Other animal products such as pig and poultry (carcass and egg) are much more efficient, with contributions of 1.2% and 4.6% to the diet intake and with phytomass appropriation of 0.7% and 2.5% respectively.

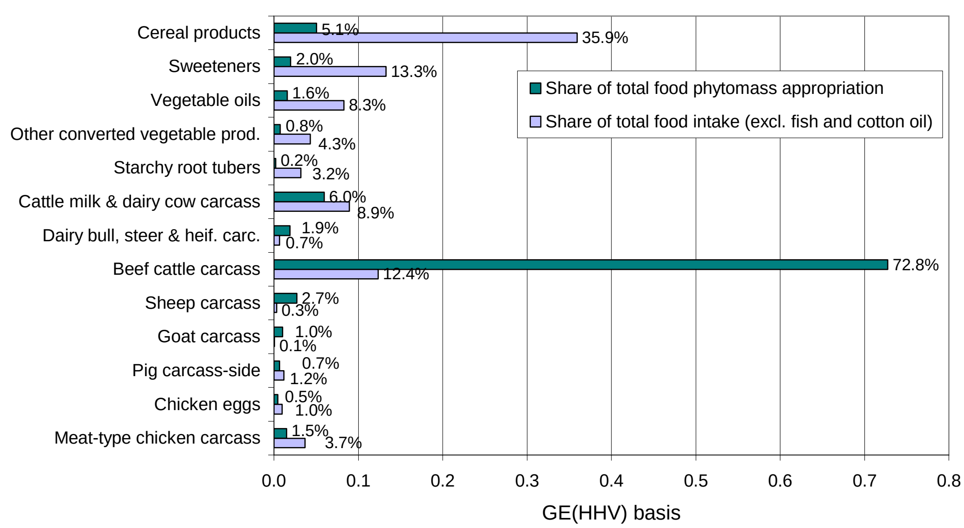

Figure 31. Share of the total food-driven terrestrial phytomass appropriation, and share of the total food intake for separate sub-systems.

4.2. *Animal food*

Animal food commodities appropriate the biggest share of the total phytomass used within the whole agri-food system. We therefore detail in this sub-section phytomass appropriation, efficiencies and biomass flows of these sub-systems.

4.2.1. Animal sub-systems phytomass appropriation

Details on the results of the phytomass appropriation for separate animal sub-systems are given. Since concepts defined by Wirsenius (2000, pp. 135) were used in this study, they are described below in order to provide a correct interpretation of numbers.

Marginal phytomass appropriation: the sub-system which uses a phytomass *product* is recognized as the inducer of a required additional or marginal phytomass production. Therefore use of phytomass *by-product* (crop by-product), by a sub-system does not include any additional required phytomass production[118].

Net use of crop by-products: is the amount of crop by-products used for all purposes by a particular sub-system, minus the amount of crop by-products in the marginal phytomass appropriation induced by the sub-system.

Net phytomass appropriation: is the marginal phytomass appropriation plus the net use of crop by-products.

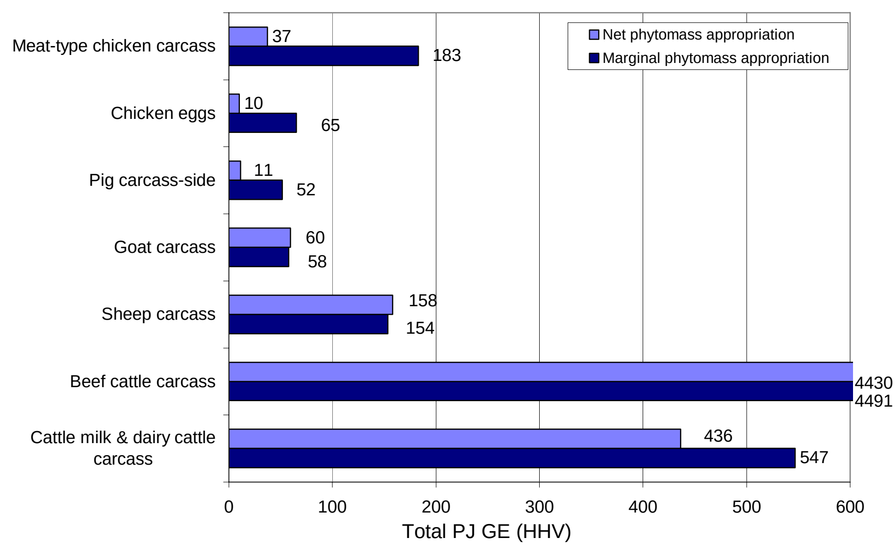

Figure 32. Marginal and net phytomass appropriation for the animal food sector.

[118] Wirsenius mentions that division in the ALBIO model into driving flows (products) and non-driving flows is not adequate, since demand for by-products influences the economic and other conditions, determining the crop production. Note that these feedbacks are not contemplated in the model.

Figure 32 shows net and marginal phytomass appropriation of each animal sub-system. Wirsenius (2000, p. 136) in his global system analysis, concluded that in most non-industrial regions, the net phytomass is larger than the marginal appropriation, due to a more vigorous use of crop by-products as feed than in developed regions.

The total marginal phytomass appropriation for animal products was 5.8 EJ; and the total net was 5.5 EJ, with a difference of only 5% (0.3 EJ). This means the country is in an intermediate situation if compared with other regions. The fact that the marginal appropriation was found to be greater than the net phytomass appropriation can be interpreted as a potential to intensify the use of by-products, e.g. for animal food production or energy purposes.

Figure 33 illustrates a phytomass appropriation induced by a domestic consumption of animal food. Note that phytomass appropriated for products which were exported are not included in the figure. Note that if products exported were included, that is actual food commodities generation, the shares of phytomass appropriation would give a totally different picture.

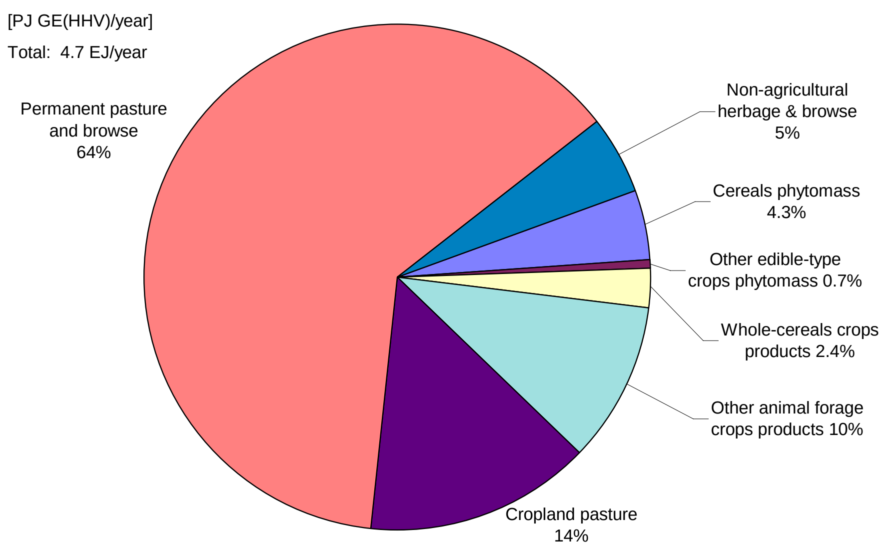

Figure 33. Phytomass appropriation for the total animal food sector. Neutral-trade.

Turning to feed matter intake, Figure 34 shows the composition of feed intake for the whole animal system. Total feed intake was estimated to 154 Tg dry matter, with an equivalent value of 2.8 EJ in gross energy terms[119].

[119] Note that the figure is on GE (HHV) basis; however shares of feed use, based on DM composition do not differ significantly.

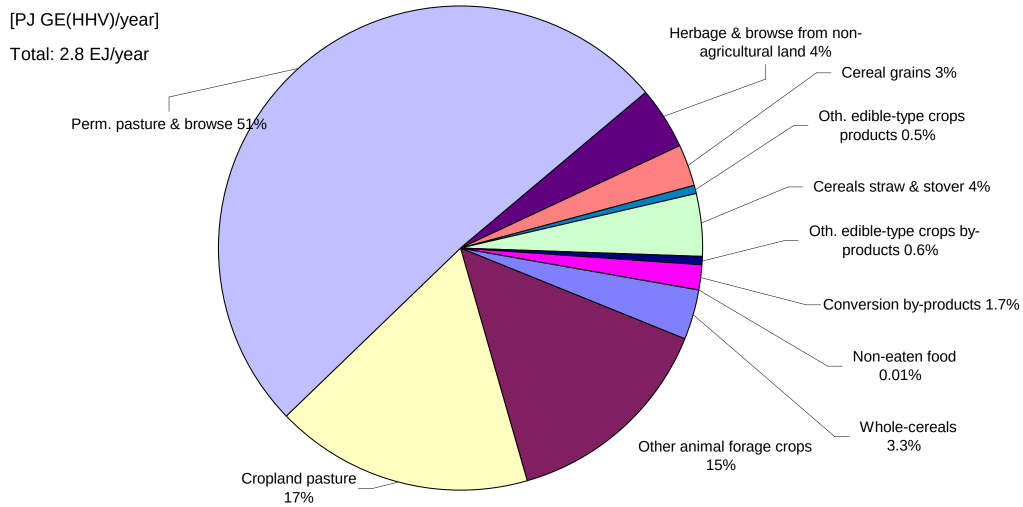

Figure 34. Feed use (actual intake) for the total animal food sector.

Permanent pasture and non-agricultural land dominates the total feed intake of the animal systems with more than 56% of the share. Cropland pasture constitutes around 17% of total feed, and around 3.3% of whole-cereals forage (whole-maize or sorghum silage). In contrast crop by-products constitute around 5% of the total feed use. Amazingly, food residues make 2% of the feed mix of pigs but only 0.01% of the total animal feed mix.

Figure 35 and Figure 36 give the average feed mixes of each animal sub-system. They show feed mixes for different ruminant and monogastric sub-systems respectively disaggregated by feed categories. As expected, ruminants have a medium diet strongly based on fibrous feedstuffs such as native and sown pastures. In contrast monogastric animal sub-systems have diets based on cereals, soybeans, and vegetable conversion by-products, mainly soybean meals.

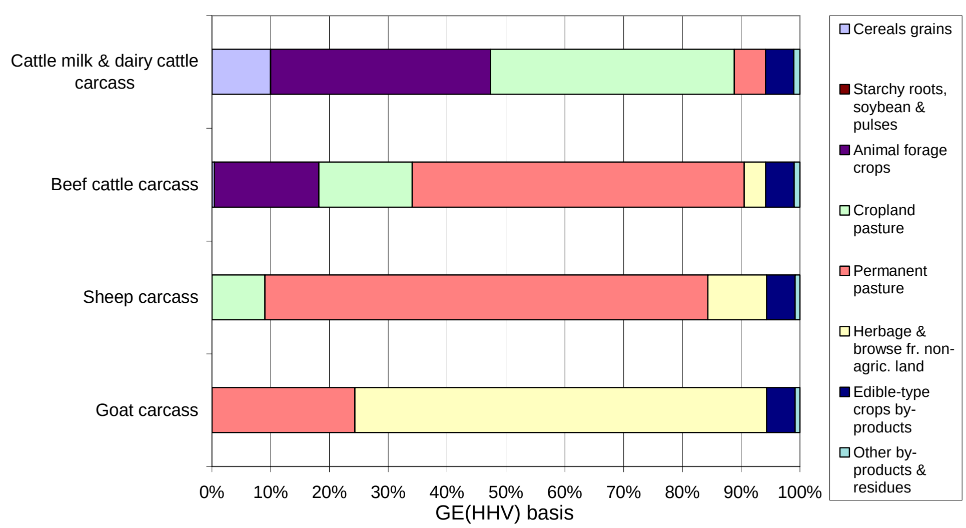

Figure 35. Feed mixes (at intake) for ruminant sub-systems.

Figure 35 shows feed mixes for ruminant sub-systems. As can be appreciated dairy cattle are feed with a considerable different feed mix when compared to beef cattle. That is more energy intensive feedstuffs are assigned to dairy cattle to assure milk production when there is no available feed on the farm. In contrast sheep and goats are reared in an extensive manner and nature mainly does the work of feeding them with permanent pasture and sometimes, with non-agriculture land phytomass.

Crop by-products were assigned proportionally to feed energy requirement by ruminant sub-system, since there were no data available for making a more accurate assignment. However this may not be reflected in reality because of two reasons. 1) Since beef and milk cattle are exploited in a more intense manner compared to goats and sheep, by-products with good nutritional value are regularly assigned to the former sub-systems. 2) Distances between by-product generation and the location of animals to feed. Since milk cattle and feeder cattle are located mainly in the Pampeana ER, where most of the by-products are generated, they take most of these by-products. However in the model most of them ended up in the beef cattle and milk sub-systems. As a consequence the assumptions in the model calculation should not differ significantly from reality.

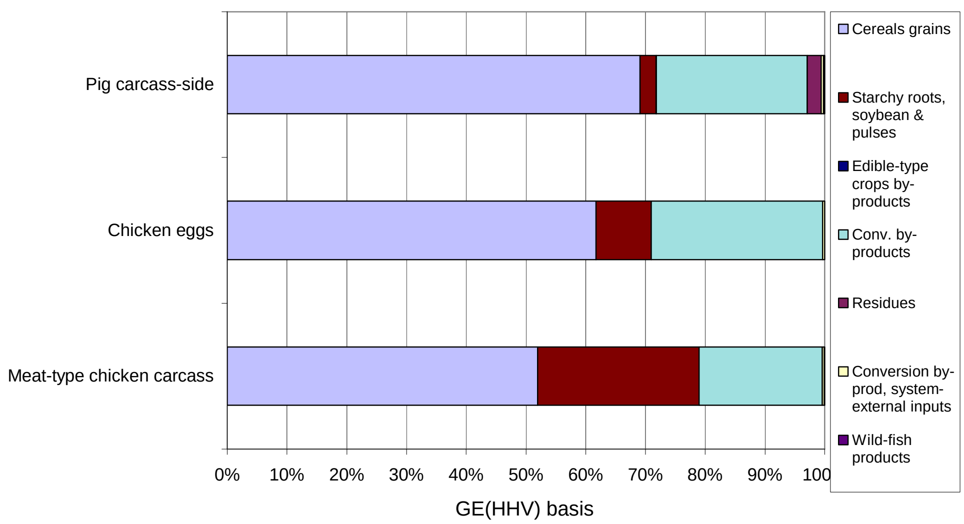

Figure 36. Feed mixes (at intake) for monogastric sub-systems.

Figure 36 shows feed mixes for monogastric animals. In comparison with ruminants, chickens and pigs have a more stable diet, with smaller variations between seasons. Therefore feed mixes are estimated with more precision. In the three feed mixes, cereals and oil crop by-products dominate, except for meat-type chickens. Food residues and system external inputs (fish meals) contribute in a very small percentage to the total feed mixes.

4.2.2. Animal sub-systems efficiencies

Figure 37 links phytomass appropriation, feed use, and food intake for all animal food sub-systems[120]. It should be appreciated from this figure that while the sum of all ruminant sub-systems appropriates 97% of the phytomass, they contribute 80% of the total animal products to a medium person diet.

Due to three reasons ruminant carcass is by far the animal sub-system with the biggest phytomass appropriation per carcass generation[121]. Firstly, ruminants contribute significantly to the share of animal products in a medium person diet. Secondly, the main feed components are permanent and cropland pastures with low pasture utilization efficiencies. Thirdly, these animals have the lowest conversion efficiency of all sub-systems from phytomass to zoomass.

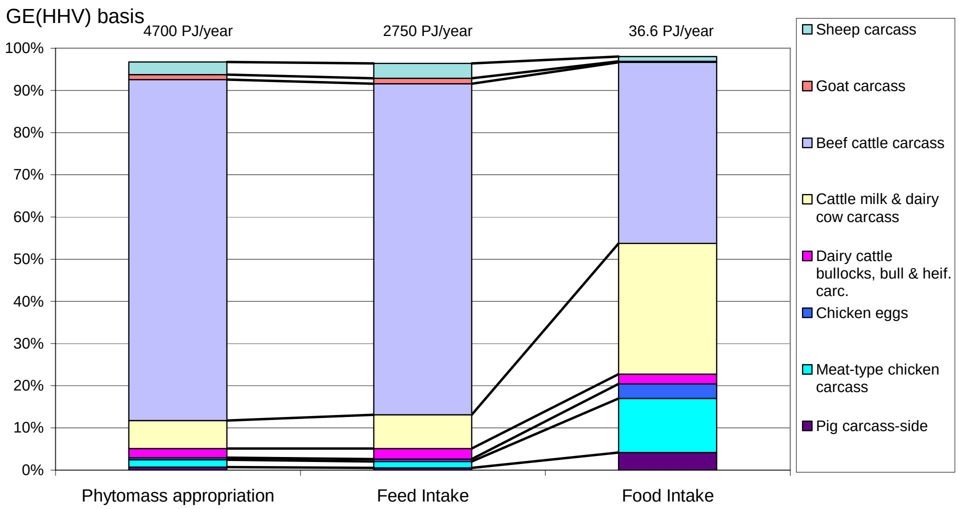

Figure 37. Phytomass appropriation, feed use (actual intake), and food intake related to separate animal sub-systems.

For milk products, the conversion efficiency is good compared with other ruminant sub-systems, but not that good in comparison with pig carcass and chicken egg and meat-type chicken carcass. Its total production is considerable compared to the total of animal products, and as such it contributes to improving the overall efficiency of the whole animal system.

Pig carcass has excellent conversion and overall efficiencies. Its contribution to improving the overall efficiency for the whole animal system is significant. However consumption could still be increased by a considerable amount to improve the overall efficiency of animal products.

Chicken egg is a commodity with very high conversion efficiency. Meat-type chicken carcass, the most efficient animal sub-system when converting

[120] Note that food intake does not include 0.7 PJ corresponding to fish products, since this activity does not appropriate terrestrial phytomass.
[121] That includes edible and non-edible parts of carcass.

vegetable to animal products, has a share of only 13% of the total intake of animal products.

The mix of phytomass appropriation and feed use per output for different animal sub-systems are described in the following figures. That is, phytomass appropriation per animal food intake is shown in Figure 38[122].

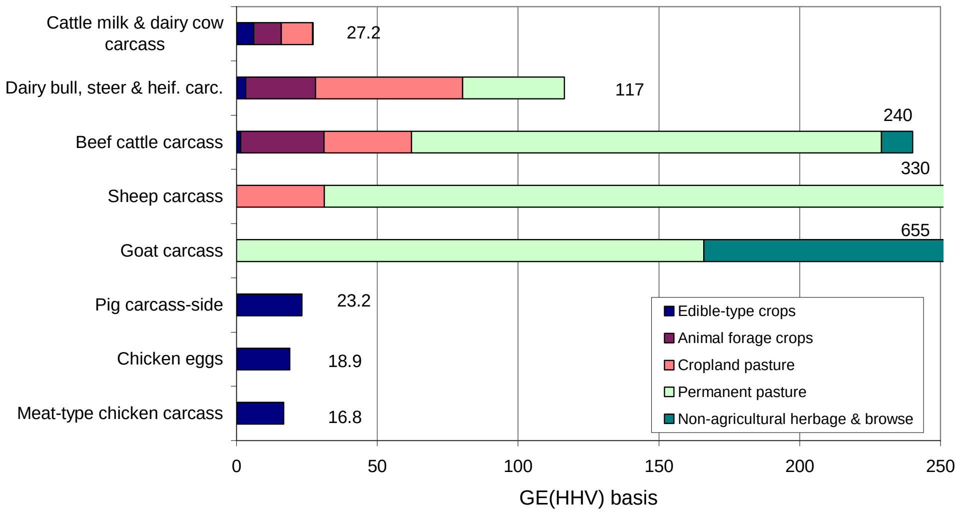

Figure 38. Appropriation of phytomass per food intake for separate animal food sub-systems.

Note that since sheep and goat are less selective when pasturing than cattle[123], pasture utilization differs between ruminant sub-systems. This is a good reason for farmers to have crops and a mix of ruminants (cattle and sheep or goats). Crops are harvested and afterwards cattle are allowed to graze straw and stover left in the field. Later on sheep graze what cattle did not eat which is used by farmers to improve firstly crops utilization, and secondly pasture utilization.

Figure 39 shows the same animal sub-systems as in Figure 38, but in this case feed intake per product generated, that is feed intake per unit of commodity generated on gross energy basis (whole carcass, including non edible parts) for each animal sub-system.

Sheep and goats are by far the most inefficient sub-systems. However it has to be noted that sheep contribute other products than just food. That is, they are an animal sub-system with two purposes, they produce wool and carcass, and this is not reflected in these figures[124].

[122] Sheep and goat sub-systems bars are cut in Figure 38, in order to not distort the graph, since their phytomass appropriation by unit of output is much higher than other animal sub-systems.
[123] If sheep and goats are not managed properly, they eat the entire plant causing damage beyond plants recovery.
[124] Goats are also sometimes used for other purposes.

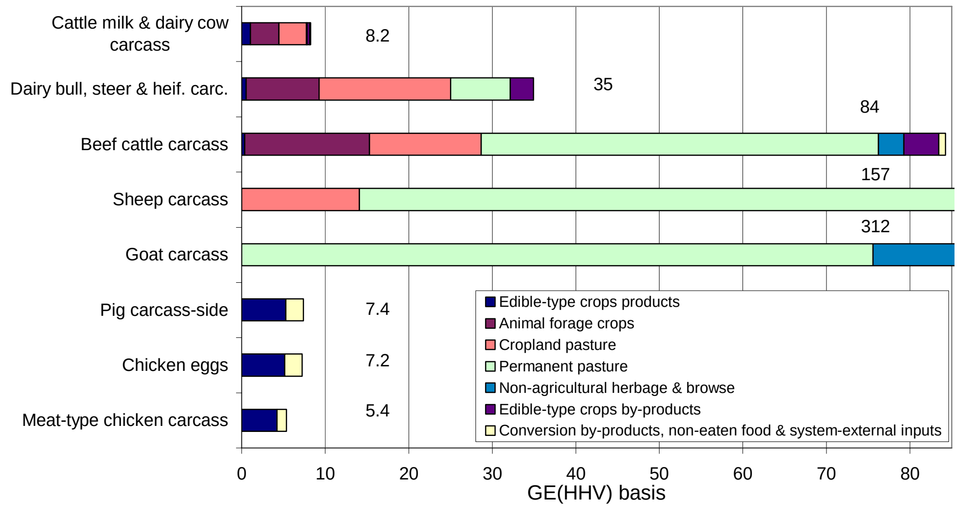

Figure 39. Feed use (actual intake) per product generated for separate animal sub-systems.

4.2.3. By-products contribution to the agri-food system

Table 21 shows values of phytomass appropriation by animal sub-system. Note that the net phytomass appropriation includes, in addition to the marginal appropriation, the "use of crop by-products for bedding" and the "use of crop by-products as feed". What does a negative value of net use of by-products mean? It does not mean negative consumption of by-products. But that when an animal sub-system takes fewer by-products than it generates[125], its net use is negative. This is the case for cattle milk, pig carcass, chicken eggs and meat-type chicken carcass.

Due to extensive use of crop by-products as feed, ruminant meat-type sub-systems have a positive net use of crop by-products. Despite this, for the ruminants group the net use of crop by-products is a mere 2.4% of the marginal phytomass appropriation. For pig and poultry sub-systems, the pattern is very different. Most of products which are used to feed these animals generate crop by-products, and although some by-products are used as feed or for bedding, the amount induced is considerably bigger.

Most of the phytomass appropriated by animal sub-systems are usable as by-products feed. However, nowadays they are not used by animal sub-systems. If sub-systems are analyzed individually, we may think of big inefficiencies, since they generate big amounts of by-products which they never use. However when agriculture is planned and organized different sub-systems can complement each other. What a sub-system generates as by-product (or residue) the other could take as an input. Even this complementation exists, the whole animal system generates more by-product than it consumes and therefore the complementation can still be improved considerably.

[125] A consequence of an animal sub-system consuming a product is that a by-product is generated.

Since assigning low amounts of litter for bedding to the ruminant sub-system, the use of crop by-products for bedding was negligible if considering the whole animal system, amounting to only 10 PJ in gross energy terms, or less than 0.2% of the total marginal appropriation. However the meat-type chicken sub-system uses a considerable amount of its net phytomass appropriation for bedding.

Sub-system	Marginal phytomass appropriation	Net use of crop by-products	Net phytomass appropriation
Cattle milk & dairy cow carcass	428	-111.8	317
Dairy bulls & heifers carcass	119	1.0	120
Beef cattle carcass	4441	68.7	4510
Other animal carcass	225	5.8	231
Sheep carcass	154	4.7	158
Goat carcass	58	1.8	60
Pig carcass-side	52	-40.4	11
Chicken eggs	65	-54.9	10
Meat-type chicken carcass	183	-145.8	37
Total all sub-systems	**5725**	**-271**	**5454**

Table 21. Marginal and Net phytomass appropriation for separate animal sub-systems. All values are in PJ GE (HHV).

4.3. By-products and residues

In the previous sub-section we presented results on the magnitude of the resources used to produce animal commodities. In this section we now present results regarding the output, or waste side of food production[126]. The purpose is to give an overview[127] of the overall system, that is, inputs and output of the agri-food system.

4.3.1. Generation of animal manure

During the analyzed year a total amount of animal manure of 1.25 EJ or 82 Tg of DM was generated within the country. Figure 40 shows the manure and used littler generated per unit of product in GE (HHV) basis. Cattle milk products and monogastric animal products do not generate relevant amounts of manure when compared with beef cattle carcass. Beef cattle carcass sub-system takes the biggest amount of feed per product. It therefore generates the biggest amount of manure (87%). Pig and poultry products generate only 1.9% of the total manure generated. The sum of sheep and goat sub-systems[128] generate only 6% of the total manure[129].

[126] These output flows can also be considered by-products
[127] The system perspective overview is an Industrial Ecology method to analyze flows. See page 2 for a detailed description of IE.
[128] Note that the bars in Figure 40 are cut to avoid distortion of bar scale.
[129] Note that all numbers presented below refer to actual or total numbers, including manure or methane induced from exported products.

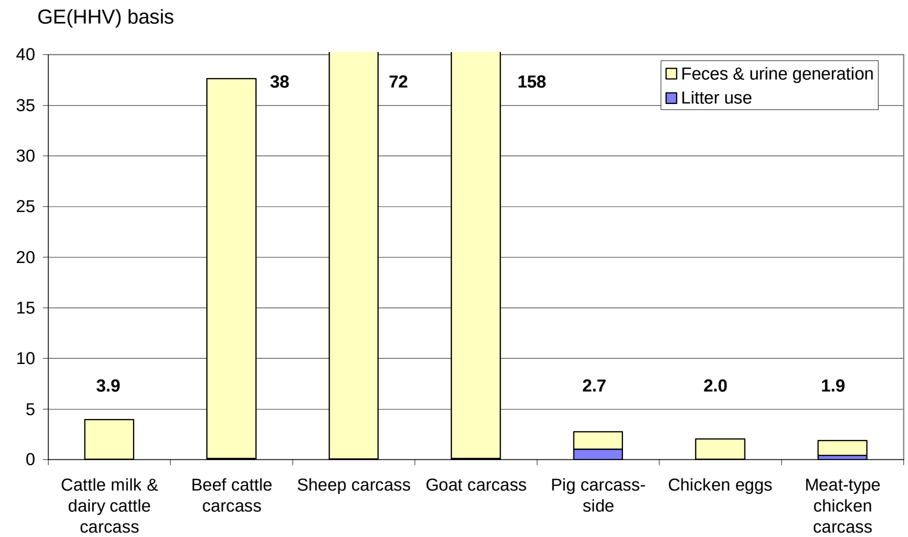

Figure 40. Manure generated (faeces, urine and used litter) from animal food sub-systems per product generated.

4.3.2. Generation of methane by animal sub-systems

Methane is an important waste flow from animal sub-systems into the environment[130]. The total amount of methane from ruminant fermentation was estimated to be around 157 PJ. Obviously beef cattle carcass accounted for the greatest share of the total with around 81%, while milk cattle & dairy cattle carcasses accounted for around 10%. Together sheep and goats carcasses generated 5% of the total methane. In the model the remaining 5% was attributed to "other animal" carcass products. Figure 41 shows estimated values of production of enteric methane per unit of animal food product.

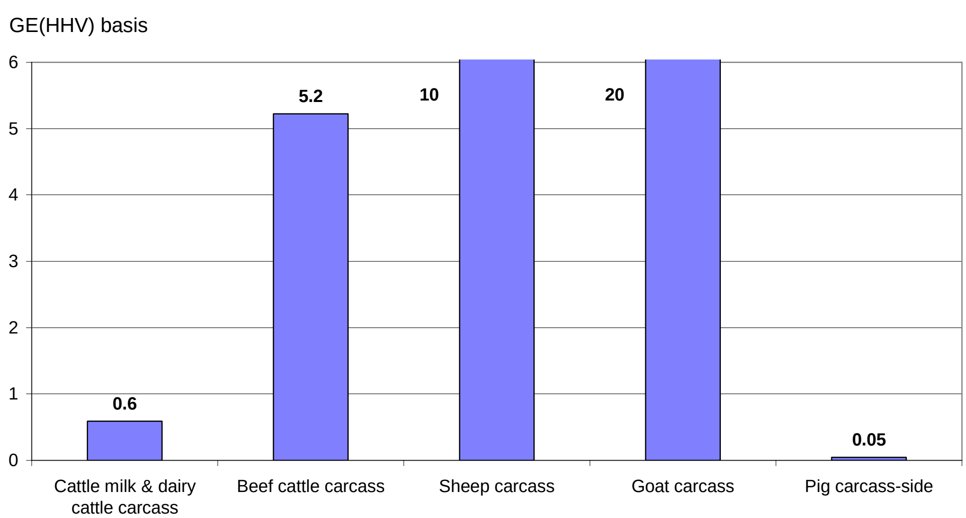

Figure 41. Methane generated from enteric fermentation from animal sub-systems per product generated.

[130] Note that only the methane produced in the rumen of ruminants (or "enteric" methane) was estimated, not the methane generated during storage and handling of manure.

4.3.3. Phytomass by-products and residues generated

Figure 42 gives an overview of the total amount of by-products and residues (excluding heat and methane) that are generated in the agri-food system. A total of 3.6 EJ was generated, which corresponds to around 207 Tg of dry matter. Figure 42 shows that residues generated between end-use (non-eaten food) and food intake account for only 2.5%. Animal manure with a total share of 35% is the dominant by-product generated. Crop by-products accounted for 48% and vegetable converted by-products for 14%. Animal conversion by-products (mainly slaughter by-products), shown in Figure 42, are of minor importance.

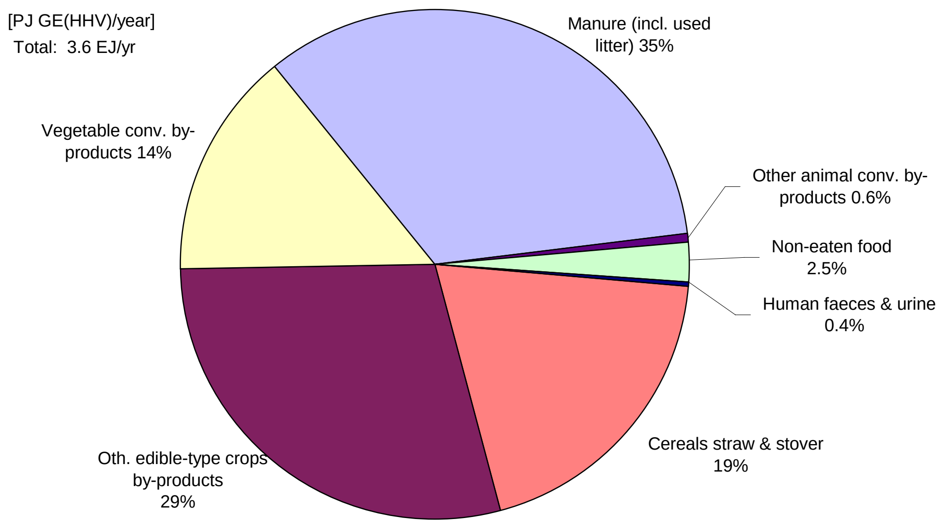

Figure 42. Generation of by-products and residues of phytomass that originated in the agri-food system (excluding heat and methane).

It should be taken into account that a unit of energy lost at the end of the food chain entails wastage of much greater amounts of phytomass and other resources to produce this unit of food. The later the losses occur in the food chain, the greater unnecessary appropriation of phytomass. Therefore any focus increasing the overall sub-systems efficiencies should concentrate on the last steps of the food chain.

4.3.4. By-products and residues fates

Figure 40, and Figure 42 shows amounts of residues and by-products generated within the agri-food system. However nothing has been described about final fates of these residues. Where do solid and liquid by-products and residues end up? Gaseous emissions go directly into the air, whereas the solid and liquid outputs end up in watershed or into the soil, and remain there or are subsequently moved into the watershed or into the air. Figure 43 shows the amounts of by-products and residues (in PJ, GE (HVV)) for which no use within the agri-food system was specified. Note that heat and methane are excluded from these results

In this sub-section results should be read carefully. Results presented are not intended to be answers. Instead they are presented with the intention of asking some questions to be answered through further research of final fates. A more careful study is needed to accurately describe final fates after biomass has been used as food, feed, energy or land conservation.

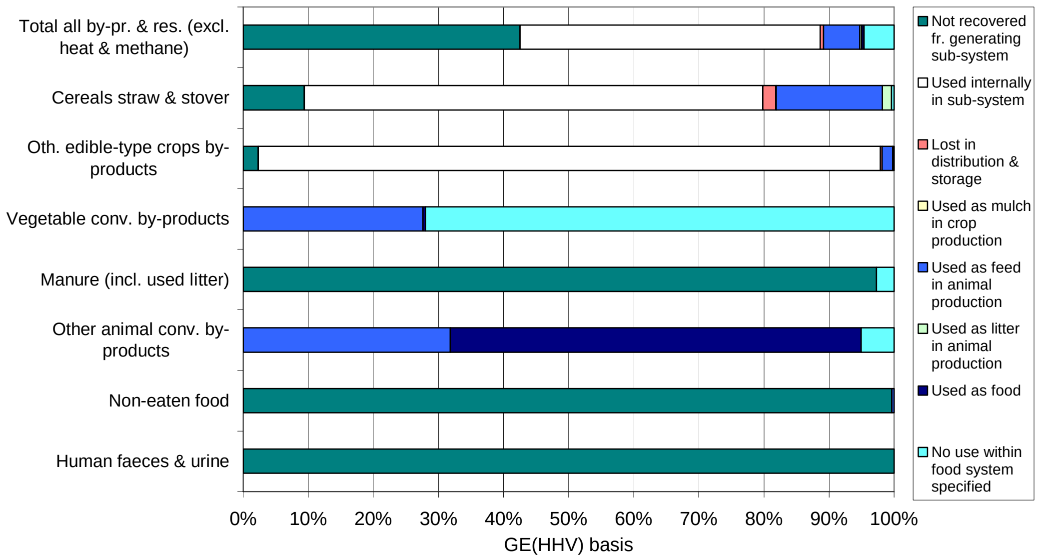

Figure 43. Fates of generated by-products and residues (excluding heat and methane).

Almost 90% of the total generated by-products and residues are “not recovered” or “used internally in the sub-system”. “Not recovered” mainly refers to pasture and cropland products not eaten by animals when grazing, and manure left on the field, but includes as well in minor quantities non-eaten food and human feces and urine. “Used internally" comprises mostly of crop by-products left on the field for land conservation. The fates of residues or by-products categories are described below.

a) **Crop by-products**. Main fate is internal use which means that when crops are harvested most of the plant stays on the field for land conservation. The categories “not recovered from generating sub-systems” and “no use within the agri-food system specified” may also imply by-products left on the field after ruminants graze them. Therefore all these crop by-products fates have a role in land conservation.

b) **Vegetable conversion by-products**. The fate “No used within the agri-food system specified” mainly means energy production. That is, by-products burnt as fuel in industrial boilers such is the case of sunflower husks, by-products used to produce ethyl alcohol such is the case of sugar cane molasses, and by-products used to produce paper such as the case of cane bagasse, etc.

c) **Animal manure**. For ruminants, manure excreted during grazing was essentially classified as “not recovered”. Since the beginning of the 90s beef cattle has been intensifying because of land competition. According to the CNA02 1% of cattle stock was feed in lots. Therefore 2% of cattle faeces, 90% of poultry, and 60% of pig sub-system, comprise the amount “No use within agri-food system specified”.

d) **Other animal by-products** include dairy cattle carcass and leghorn-type chicken carcass which end up “used as food”. It also includes animal fifth quarters which end up as “animal production feed” and “no use within agri-food system specified”. A description of animal fifth quarters can be read on page 44

e) **Non-eaten food** includes food waste from retail, households, large kitchens, etc. The only assumption was non-eaten food “used as feed in animal production”. However this value is underestimated. In reality ruminants sometimes use food residues as feed as well.

f) **Human feces and urine**. No statistical data was used to make assumptions. However they constitute a very low share of the total amount of by-products and residues generated within the agri-food system. The entire generated amount was assumed to have not been recovered from the system.

5. Discussion

In this section we discuss and compare our results with other studies and data sources. In addition, we comment on the major tendencies of the agri-food system, discuss data source accuracy, and make some recommendations.

5.1. Argentinean vs. others agri-food systems

It is very important to know the efficiencies of Argentinean agri-food system. However if is not compared with other systems, we will not be able to know if we are more competitive or sustainable than countries or regions with similar economic activities or geographic characteristics. Therefore to fulfill this need, we compare our results with other studies in this sub-section.

5.1.1. Animal food production

Results obtained for the country seem to be coherent when compared with results obtained by Wirsenius (2000, pp. 155 to 157). An interesting remark when comparing Argentina with the West Europe beef cattle sub-system (open field vs. confinement), is that to produce a unit of beef cattle, Argentina appropriates twice as much phytomass. However when comparing animal feed intake per product generated it is only 25%. This gives us an idea of where efforts should be focused to improve the overall efficiency. A similar pattern can be seen for other ruminant sub-systems, such as sheep and goats. When comparing chicken and pig sub-systems commodities, no significant differences in efficiencies are observed with other world regions.

According to Wirsenius (2000, p. 163), on an overall efficiency basis, the efficiency gap between developed and undeveloped countries tends to be smaller, because end-use losses tend to be lower, and use of by-products as feed is more frequent in less affluent countries. However the results obtained in this study suggest that Argentina’s losses and use of by-products as feed are of magnitudes comparable to those in affluent regions. This is mainly because of extensive system ruminant production, which appropriate considerable amounts of phytomass from large areas instead of using more crop by-products.

5.1.2. Efficiencies

From the results of the model it can be appreciated that most of the phytomass appropriation is for the production of animal food commodities, in particular that of beef cattle. This animal sub-system dominates the shaping of the phytomass appropriation for the whole agri-food system. What are the reasons? First of all, consumption per person of this meat-type is by far the largest (that is, beef was almost three times the second meat-type, chicken meat), and secondly because of biological parameters of this animal specie, such as reproduction and growth rates, the conversion efficiency is very low when compared to other animal sub-systems.

The results section showed that conversion efficiencies are different among sub-systems. Vegetable food conversion efficiencies are higher than animal food, and among the former the lower efficiencies are for ruminants. However it may not be fair to compare efficiencies as presented. That is, each animal sub-system has a medium feed mix, which can not be compared straightaway. Ruminants are fed with fibrous feedstuff mainly. Around 95% of the cattle diet is based on fibrous products and by-products, and more than 60% comes from permanent pastures.

In some way all ruminant sub-systems are contributing to improving the amount of edible food, since if fibrous phytomass are not converted by these animal sub-systems, it would end up as phytomass not used in the agri-food system. We should notice that 75% of the appropriated land by system is of permanent pasture and non-agriculture land, and if it was not used by the ruminant sub-systems to convert phytomass to zoomass, it wouldn't be used to produce any other food type.

Therefore, what is the criterion we should use to compare conversion efficiencies by food sub-systems? Wirsenius (2003, p. 75) discusses it, and concludes that comparison should be based on competition for cultivable land. That is, what the food sub-systems compete for is the cultivable land where production options are feasible.

Even though the production of ruminant meat in Argentina through all of its history was based on an overwhelming majority of fibrous feedstuff, the tendency is now to change the feeding composition. If this tendency persists a new analysis will be needed to see competition for arable land among meat-type sub-systems. Obviously cattle fed with a higher proportion of crops, would give a different picture compared to the traditional cattle diet. Actual trends are discussed further in sub-section 5.5.2.

Contribution of cattle to human welfare is not completely captured if conversion efficiencies are only compared. That is, low energy conversion efficiencies are not always bad. As explained by Wirsenius (2000, p. 231) although food is the main service supplied, it may also provide services other than food, such as draught power, dung, wool, leathers, etc. That is, sheep wool, cattle leather and goat hair should be included in the agri-food system model, since these by-products add value and therefore increase outputs.

Furthermore, according to Wirsenius (2003), if adopting a wider perspective on the use of biomass, it could be argued that fibrous feedstuffs eaten by ruminants, particularly crop by-products compete with other crucial fates such as land conservation, fuels, and feedstock used for material construction.

It should also be kept in mind that water, nutrients, fuels, and other resources, which are not included in this study, are also appropriated when producing food commodities. Furthermore, energy alone does not reflect the whole nutritive value of food. The efficiency in the production and conversion of other crucial nutrients, such as proteins, vitamins and minerals should also be considered when analyzing different food sub-systems.

5.2. *Model accuracy*

With the purpose of validating and showing the model limitations, we intend to discuss data sources and assumption accuracy of the model.

5.2.1. Animal sub-systems

As shown in the results section, animal food commodities appropriate the greatest share of the total phytomass generated within the agri-food system. Therefore is central to discuss model assumptions to see the validity of obtained results.

Productivity

With the purpose of showing strengths and weaknesses of model calculations, the following are compared with reference data sources: assumed values for productivity, stocks, and numbers of slaughtered animals

<u>Comparison of animal sub-systems productivity</u>

Productivity parameters influence the model calculations of stocks and total feed energy requirements. Therefore it was crucial to assume values which were as close as possible to available data.

	Productivity Parameters	FAOSTAT	Study
Cattle	Production of milk per dairy cows in stock [kg as-is]	4099	4098
	Offtake (slaughtered per cattle in stock)	25%	24%
	Average carcass weight [kg as-is]	213	212
	Production of carcass per cattle in stock [kg as-is]	52.4	51.3
	Production of milk per cattle in stock [kg as-is]	161	161
Sheep	Offtake (slaughtered per sheep in stock)	38%	34%
	Average carcass weight [kg as-is]	10.8	12.0
	Production of carcass per sheep in stock [kg as-is]	4.2	4.1
Goat	Offtake (slaughtered per goats in stock)	35%	36%
	Average carcass weight [kg as-is]	6.6	6.5
	Production of carcass per goat in stock [kg as-is]	2.3	2.4
Pig	Offtake (slaughtered per pigs in stock)	133%	157%
	Average carcass weight [kg as-is]	63.6	60
	Production of carcass per pig in stock [kg as-is]	100	94
Poultry	Offtake (slaughtered per chicken in stock)	351%	469%
	Production of carcass per poultry in stock [kg as-is]	7.5	9.0
	Production of eggs per poultry in stock [kg as-is]	2.9	3.2
	Average carcass weight [kg as-is]	2.2	1.92

Table 22. Generation of animal products according to FAOSTAT and this study.

Table 22 shows the matching of assumed model values on animal sub-systems with FAOSTAT data. The output values from the model seem to be in accordance with FAOSTAT. Assumed values in the model were taken from calculations. Instead FAOSTAT does not estimate these values; rather they simply use a set of collected data provided by INDEC of varying accuracy.

Accuracy of animals in stock

The stock estimation of animal categories in animal sub-systems depends on carcass production, productivity parameters, carcass yields and slaughter weights. In addition, stocks vary substantially over the production cycle, since culling and births normally take place at specific times during the year.

Obviously, the moment in the production cycle when the census is done affects total number of animals in stock[131]. The model estimates an average stock value for the entire year. Therefore we should be careful when comparing the model estimates of stocks with data sources, such as the CNA02.

Estimated *cattle* stocks in the model show a good match with major data sources (see Table 23). Guideline sources were SAGPyA and not CNA02, since estimates from the former are more updated. Even though, since SAGPyA does not distinguish by animal category, the CNA02 data was used to estimate shares of each animal category.

For *sheep*, different data sources show considerable differences in reported stocks. According to ONNCA, official supervised animals slaughtered amounted to 177 thousands heads during the year 2003, close to the 10% of the 1.45 millions heads estimated by FAOSTAT[132]. Model estimations should be fairly accurate because were estimated with a whole sub-system data consistency, and the total stock in the model is close to SAGPyA data.

For *goats*, model estimates of stocks do not match with any of the available data sources. Estimated total stock matches with CNA02 data, and is 5% lower than the FAOSTAT data. This difference may be due to underestimation of carcass generation. However since the phytomass appropriation by this animal sub-system is less than one percent of total, differences in stock do not affect significantly the estimated total phytomass appropriation for all animals.

Pig stock in the model is lower than data sources, and may be due to optimistic assumptions of productivity parameters. Regarding average carcass-side weight, it seems that model estimations are slightly smaller than FAOSTAT data, which may explain the higher stock rotation in our study. However estimated values have good matching with FAOSTAT data.

Poultry is the sub-system which presents the largest differences in estimated stock in comparison with data sources (see Table 23). These differences may be due to the fact that poultry stocks vary considerably over the year and because very different carcass weights were assumed in the model compared with FAOSTAT data. According to local sources data, model estimations should be correct.

[131] CNA02 reports animals in stock by the 30th June 2002.
[132] This is in accordance to what SAGPyA estimates as percentage of official supervised animals slaughtered in relation to real values.

Animal sub-systems	Study	CNA02	SAGPyA[133]	FAOSTAT
Cattle	50,993	47,527	51,000	50,869
Dairy cows	2,000	2,005	2,151	
Beef cows	19,385	17,709	19,003	
Replacement heifers	8,798	4,585	4,920	
Bulls	1,019	950	1,020	
Replacement bullocks	616	236	254	
Steers	13,753	14,291	15,335	
Heifers	5,423	7,751	8,317	
Sheep	12,584	12,559	15,000	12,450
Ewes	8,053	7,113		
Lambs		931		
Replacement ewe hogget	3,025	1,451		
Rams	443	410		
Replacement ram hogget	129			
Ram hogget	656	2,654		
Ewe hogget	277			
Goat	4,040	4,061		4,200
Does	2,354	2,359		
Kids				
Replacement doe kids	587	601		
Bucks	118	112		
Replacement buck kids	22			
Buck kids	659	990		
Doe kids	301			
Pig	1,432	2,185		1,500
Breeding sows	134	388		0
Piglets	222	744		0
Replacement gilts	52	124		0
Swine	1,024	681		0
Leghorn-type chicken	26,493			103,999[134]
Laying hens	20,219			
Breeding hens	288			
Replacement pullets	5,986			
Meat-type chicken	60,147			
Breeding hens	2,218			
Replacement pullets	1,401			
Broilers	56,528			

Table 23. Comparison of animal stocks from this study with data sources (in thousands).

Accuracy of number of slaughtered animals

Regarding slaughtered *cattle*, even though there is a small difference between model estimations and data sources (see Table 24); the estimated amount of produced carcass by cattle category corresponds with ONCCA values.

Category	Study		ONCCA	
Steer	6,402	52%	6,782	54%
Heifer	3,451	28%	3,376	27%
Bull	207	1.7%	185	1.5%
Cow / milk Cow	2,262	18%	2,163	17%
TOTAL	**12,321**	**100%**	**12,506**	**100%**

Table 24. Slaughtered thousands head according to this study and ONCCA.

[133] Values estimated by Censos Agropecuarios, Estimaciones SAGPyA, Encuesta Nacional Agropecuaria. Animal categories stocks are own estimations, based on proportions of heads per category in CNA02.

[134] Note that the total stock of poultry given by FAOSTAT, was calculated in chicken equivalent terms.

Regarding the number of slaughtered *sheep* animals, the difference is in the share of animal categories in the total number of slaughtered animals and assumed live weights. Assumed values in the model were taken from calculations[135].The number of slaughtered animals estimated seems to be in accordance with FAOSTAT data.

For *goats*, assumed live weights and share of each category in the total carcass production affects the number of animal slaughtered to be assumed. However the estimated numbers of slaughtered animals in the model were identical to FAOSTAT reported data[136]. The methodology used to estimate average carcass weight of buck/doe kids in this study, can be considered accurate. The carcass weight is hard to estimate precisely as well. Based on different information sources, it could be assumed that carcass weight values are within a considerable range. For example, the San Javier goat meat processing plant, located in Córdoba province, slaughters buck/doe kids of 4-5 kg, 6-9 kg, and does of 45 kg. At the same time in Buenos Aires province, there are some goat farms producing milk, which raise buck kids slaughtered at 45 kg of live weight.

Regarding the number of slaughtered pigs, model calculations show a 10% over FAOSTAT data, and this is explained by a lower assumed value of carcass-side weight. That is, while 60 kg [as-is weight] was chosen in this study, FAOSTAT published an average value of 63.6 kg.

Regarding slaughtered *chickens*, the model calculation gives 406 millions heads, while FAOSTAT reports 355 millions chickens heads equivalent. The difference is due to different carcass weights: FAOSTAT states an average of 2.2 [kg as-is weight] for the whole-poultry system, while in the model calculation we assumed 1.9 kg. Even the model assumptions may show more consistency than FAOSTAT data, can not be stated that model calculations are correct.

Table 25 shows FAOSTAT data and estimated values from this study, with the purpose of comparing the data accuracy of the model output values.

Animal sub-system	FAOSTAT	Study
Cattle	12,506	12,321
Sheep	4,780	4,321
Goat	1,450	1,470
Pig	2,002	2,250
Poultry	354,583	406,772

Table 25. Slaughtered thousands animals according to FAOSTAT and this study

[135] In the Patagonia ER the number of lambs weaned per ewe-in-stock is around 56%. Similarly, in the Pampeana ER, which holds 13% of the sheep stock, is estimated 0.99 lamb weaned per ewe-in-stock. For the Mesopotamia ER, with 9% of the total stock, is estimated a value of 0.7 lambs weaned per ewe-in-stock. All these assumptions give a medium value of 0.63 lambs weaned per ewe-in-stock

[136] Since most of this animal sub-system activity is informal, there are no good supporting data for our assumption. Estimation varies among sources, and there is not a unique real value. A higher carcass generation value was assumed, with the purpose of getting closer the number of slaughtered animals estimated in the model with values published by FAOSTAT. Despite the effort to match the numbers, our estimations of slaughtered animals are still well bellow FAOSTAT data. The only reason for this mismatching can be explained by incorrect data published by FAOSTAT.

Feed use

<u>Accuracy of feed nutrient densities</u>

For many feedstuffs, such as cereal grains and starchy roots, the variations in nutritive value are rather small. They can be based on sources such as the NRC tables of feed composition. However, for some crops, especially crop by-products, such as cereal straw and forages, the variation in nutritive value is substantial, with large variations over the growing season and among regions.

Permanent pasture and herbage from non-agricultural land are among those feedstuffs with the greatest variation in nutritive value. Since these feedstuffs make up considerable shares of the ruminant feed mixes, variation in assumed values greatly affect the total amount of feed required, and therefore methane and manure generation.

Since data was assumed to be looking for phytomass generated and land use global matching, assumed values are not necessary real values. Instead they are intended to represent an average value contributing to the global matching of the agri-food system.

Jaurena *et al.* (2006) treated this variation by giving the medium nutritive value for each feed item, as well as the median value and the standard deviation. A sensitivity analysis of nutritive composition for crop by-products and permanent pasture should be done to see how different values influence the final results of the model.

<u>Accuracy of energy expenditures for grazing</u>

Energy requirements for grazing are not equal for all ruminants. Sheep normally graze on land with low phytomass availability, and need to walk long distances to get enough feed. Goats frequently pasture in areas with steep topography. Therefore, both sheep and goats regularly walk considerably more than cattle. Different pasture types were assumed for each of the ruminant systems, and extra energy expenditures for grazing were assumed for each of the pasture types. Therefore there is a fairly good approximation of the energy expenditures for grazing.

<u>Feed energy requirements</u>

As can be seen in Table 10, values of nutrient density requirements guidelines are close to the obtained in the model calculation. However, in most cases model values are slightly higher than guideline values. This means that assumed feed mixes may contain more than enough energy and proteins to not restrain the animal sub-system development.

Accuracy of feed mixes

The assumed average feed mixes for each animal sub-system was based on typical ER diets. The criteria and priorities used in the model calculation to allocate feedstuffs seem likely to represent reality accurately enough. However, there was no data available for actually confirming assumptions since organizations provide information based on the region where they work and have experience.

An important data gap identified in the agriculture organization and planning is the scarce information regarding feedstuffs assignment. This means that there exists no proper planning and control of feedstuff by any public institution. Production and consumption seem to be regulated by market prices rather than by official national feedstuff management.

Feed for cattle. Although there is a huge amount of maize grains being produced, it is not used to its full potential in Argentina. Livestock still mainly are fed freely on pastures. Its use as cattle feed could contribute to improving productivity and profits for farmers. The chosen feed mixes for these sub-systems could be discussed in further depth, since no single resource was used to define them.

Feed for sheep. The feed mixes are relatively simple, and we believe that assumed values do not differ significantly from reality. Variation of feed mixes may exist in Pampeana ER, since the diversity of available feedstuff is greater. Therefore a wrong estimation is possible in this ER.

Feed for goats. Types of land assumed (permanent pasture and non-agricultural land) where these animals are fed may deviate from reality, since assumed values are based on the number of animals located on non-agricultural land. Note that phytomass appropriation would not differ significantly. That is results would be similar even if assuming a larger share of permanent pasture in the feed mix.

Feed for pigs. Since feed mixes are rather quite similar for most of pig producers no great variations could be found when estimating total feed used. GITEP (2003) estimates that use of maize, sorghum, and soybeans as pig feed was 740 thousand tons [as-is weight] in 2003. These study estimations were 593 thousand tons of concentrated and 205 thousand tons of protein supplements. The model values can be considered rather accurate for this sub-system.

Feed for poultry. Assumed values are not likely to differ significantly from real values, since pig and poultry feed mixes are standardized. In the model calculation, grain used as poultry feed represents around 29% of total grain used as feed (maize & sorghum), while 64% of the protein meals used in the internal market as feed was estimated for these animals sub-systems.

Phytomass appropriation

As can be seen in Figure 18, animal feed dominates the phytomass appropriation of the agri-food system. Pasture utilization values were assumed for each ruminant sub-system and pasture-feed category. However, chosen values may imply somewhat inaccurate assumptions, since pasture utilization varies between farms, regions, animal categories, and forage species. Despite this simplified approach, it is likely to have made relatively good estimates of the phytomass appropriation for each ruminant sub-system.

A similar comment can be made for the use of one single medium nutrient composition for each of the permanent pasture categories, since in the real system; large variations exist between seasons and permanent pasture species. It is common that milk cows and feeder heifers/steers are located where best and more abundant pastures are available, and sheep, goat and breeding cows where pasture conditions are less favorable. Therefore, model results may be somewhat inaccurate, not showing these differences in phytomass appropriation.

Note that the surface grazed of non-agricultural land is a known value by CNA02. However the amount of phytomass extracted is based on own estimation. A deeper analysis should to be undertaken, differentiating pasture utilization by ERs.

5.2.2. Distribution and storage

Losses in FAOSTAT are defined as the share of domestic supply, whereas PRECOP defines losses as share of harvested amount (production). In the model calculation, values are in the range of 4 to 14% of domestic supply (domestic production minus exports minus seeds). If we use the same definition as PRECOP, model values are in the range of 2 to 12%, with an average of 2.7% for cereal crops.

Assumed values in the model calculation are lower than published by PRECOP (2005). Furthermore, in the model losses are defined as percentages of supply, instead of losses in total numbers. Therefore if there were differences in production between model and real values, modeled losses would be somewhat inaccurate.

There is no national statistics which quantifies D&S losses (see page 33). However the data used in the model calculation fit well with other estimations. Since losses in this stage of the food chain seem to be considerable, and no systematically collected data is available, further study needs to be done of handling, transporting and storage activities, to assess losses.

5.2.3. Food intake

There is a wide range of estimates and findings on food losses in the end-use phase. According to Peckcan et al. (2005) most estimates of food wastage are between 10 to 15% of food consumption. The variation in estimates could be explained by different ways of defining and measuring food wastage, methodologies, samples size, geographical location and household characteristics.

The methodology used to estimate food wastage, was to find the difference between food end-use and food intake. Since we expect to have assumed accurate values for food end-use, when we compare assumed food intake value with other data source we may be able to know if food wastage estimation are accurate.

Food intake per capita was based on calculations of minimum dietary energy requirement[137] (see page 13). According to ENNyS (2006)[138] women among 19 to 49 years old are 24.9% over weight, and 19.4% are obese, with only 3.4% with low BMI[139]. If there are people over weighted, we may assume that more than the minimum requirement for food is eaten, and therefore assumed values in the model may be underestimated.

This probable miss estimation of the real food intake is because we prefer to be conservative when assuming values rather than risking assumptions without previous survey support. What may change our results? In the model we assume 65.6% food intake of the total available (end-use), this means that if more food was eaten, losses would be lower.

Another increasingly important issue is the food wastage in food service institutions, because of their increasing share of the total food supply to consumers. An interesting study would be to find out the differences in food waste among institutions and households, reasons for losses, and to define strategies to reduce them.

The losses at the last step in the food chain are among the largest in the entire system. Therefore lowering these losses is a potential measure to reduce economic losses and negative ecological impact. FAO has published some articles[140] as contribution to a better assessment, i.e. Sibirián *et al.* (2006) has proposed a methodology to estimate losses. In Argentina there have been no studies carried out on food wastage and losses, nor on food deprivation or food excess. Detailed research and actions on this issue need to be undertaken for the Argentinean food sector.

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[137] Food Security Statistics. FAO publishes the Minimum Dietary Energy Requirement for different countries. In a specified age and sex group, the amount of dietary energy per person is considered when meeting the energy needs for maintaining a healthy life and carrying out a light physical activity.
[138] ENNyS. Health and Nutrition Women and Child Survey. This survey was made by the National Health Ministry, during the year 2006. Since the results are still being processed, we used for our study some values of the preliminary results.
[139] BMI: Body Mass Index
[140] FAO security statistics. [online]. Available from: www.fao.org/faostat/foodsecurity

5.2.4. Phytomass appropriation in relation to land use

When comparing crops land appropriation, estimated model values are contrasted with the other three sources in Table 26. The purpose is to discuss the accuracy of results. If yields are not included when comparing land use, data output may not be complete to analyze the whole system. Therefore in Table 26 phytomass yields [Mg DM/ha][141] were included.

Some of the crop categories are discussed in the first sub-section with appropriated land surface output values. Forage crops & cropland pasture, permanent pasture, and non-agricultural land are discussed the chosen yields values, in the second sub-section.

Appropriated land surface

The same surface could have been sown with different crops more than once during a year. Therefore harvested area does not have to necessarily match with cropland surface. In addition to this, note that land surface when estimating crops production includes land used for seed production.

Land and phytomass category	**Study**	**CNA02**	**FAOSTAT**	**SAGPyA**
Total Area			**278,040**	
Land Area		**2,792**	**273,669**	
Food-type cropland	**38,307**	**36,973**	**32,504**	**-**
Yield	6.70			
Cereals	**9,818**	**10,062**	**9,332**	**9,709**
Yield	7.14			
Starchy roots	**104**	**74**	**110**	**-**
Yield	6.82			
Sugar crops	**269**	**238**	**295**	**280**
Yield	28.07			
Oil crops	**14,836**	**13,048**	**14,945**	**14,954**
Yield	6.31			
Other crops[142]	**1,123**	**1,123**	**2,336**	**-**
Yield	1.60			
Cotton crops	**185**	**257**	**201**	**146**
Yield	2.54			
Forage crops & cropland pasture	**12,157**	**12,170**	**5,285**	**-**
Yield	6.80			
Permanent grassland	**84,774**	**84,773**	**99,847**	**-**
Yield (above-ground production)	2.24			
Flux (eaten per ha)	0.92			
Pasture utilization	0.41			
Non-agriculture land	**27,698**	**27,698**	**-**	**-**
Extraction (eaten), Gg DM	6,295			
Flux per forest area (Mg DM/ ha)	0.23			

Table 26. Area in thousand ha; yield and flux in Mg DM/ha.

[141] 1) Amount of product harvested per unit of surface is expressed as fluxes. Note that fluxes are expressed in [Mg DM/ha], therefore they should not be compared with typical formal yields, published by SAGPyA and FAOSTAT, expressed in [as-is weight basis]. 2) Yields in the model, express total amounts generated on fields, for the whole of above-ground phytomass, including crops left on the field.

[142] Numbers for 'Other crops' includes land use for production of all crops not mentioned in the table, such as fruit, vegetables, pulses, tree nuts, stimulants and species.

Note that stock for all crops, were assumed to have null “stock change”. Therefore phytomass harvested and land requirement do not necessary have to match with statistics from SAGPyA and FAOSTAT. Approximately 2,200 Gg is the difference of harvested crop between statistical and assumed values, because of null stock change assumption.

At the same time amounts assigned as animal feed of crop products, processed products and by-products varies from year to year. A certain amount produced during a certain period does not mean that it will be used during the same period. Therefore values assumed in the model should be read as estimations of average consumption, more than real values for the analyzed period.

The difference between model results and SAGPyA in cereals surface appropriation is because alcoholic beverages were modeled as beer equivalent. Therefore an extra amount of 700 thousands of barley grain were demanded in the model when compared to statistics. Starchy root comparison is straight forward for production and yields. Therefore values are close to other sources. Sugar crops keep consistency when compared with other data. Oil crop results are still similar to FAOSTAT and SAGPyA data. Land used by cotton crops is an intermediate value between FAOSTAT and SAGPyA, with seed cotton yield of 1.25 [Mg DM/ha].

For the category “other crops”, the chosen yield is not possible to discuss since many crop-types are included such as fruits, vegetables, pulses, tree nuts, stimulants and species. The total amount of phytomass and land appropriated for this crop category is not great in comparison with the total food-type crops.

Permanent pasture, forage and cropland

For “forage crops” and “cropland pasture”, the assumed model values on yields were adjusted to match estimated land surface with guideline data. Therefore the discussion here focuses on yields rather than land area. Table 27 shows the consistency between the guideline and the outcome values in this study for these two feed categories.

	Guideline			***Study***		
	Yield [DM ton/ ha]	Surface [1000 ha]	Production [1000 DM ton]	Yield [DM ton/ ha]	Surface [1000 ha]	Production [1000 DM ton]
Conserved forage[143]	**3.5**	**10,050**	**34,900**	**4.1**	**8,520**	**34,979**
Whole-cereals silage	10.0	650	6,500	10.0	651	6,506
Grass-legume forage	3.0	9,400	28,400	3.6	7,859	28,473
Grazed Cropland	**11,9**			**12**	**3,655**	
TOTAL Cropland		**12,57**			**12,170**	

Table 27. Comparison of this study with guideline values for forage and cropland for animal.

[143] Note that harvested/conserved forage yields express the amount of phytomass collected from the field, therefore is not yield of phytomass generated which is higher, and is detailed in page 38.

“Permanent pasture” is the balancing feed for all ruminant systems. Given the permanent pasture area and the amount of permanent pasture used as feed, pasture yields, pasture ME and pasture utilization were used as the relaxing variables when having to match biomass flows and land surface.

For “non-agricultural land” feed category, our estimates were based on matching with CNA02 surface data. Animal sub-systems which use this phytomass category are goats, beef cows and possibly sheep as well. Model results regarding total phytomass appropriated from this feed category should be read carefully since no good data sources were available. The share of herbage from non-agricultural land was assumed to be 70% for goats, 10% for sheep, and 3.6% for beef cattle in the feed mix composition. Although these assumptions do not influence the total phytomass appropriation for animal food commodities, they suggest how much phytomass is appropriated from the non-agricultural land.

Note that not all land used as cropland and permanent pastures were effectively grazed by ruminants. According to CNA02 only 92% of total land used as permanent pasture and 96% cropland was pastured. Therefore we can ask where this phytomass ended up. It may be possible that those lands were harvested for conserved forage instead, or there was no use of them because of drought or flooding.

5.2.5. Methane generation

Estimates of methane production in the digestive processes of ruminants largely depend on assumed digestibility of permanent and cropland pasture, since these feedstuffs are the most important shares in the feed mixes.

Since permanent pasture and cropland present big variability of ME by regions, species and season, a sensibility analysis may be good to see possible methane emission variability when estimating.

5.3. International trade and its influence

The increasing crop production destined for export is pushing the ruminant rearing activity to the extra Pampeana ERs with lower phytomass productivity. To an increasing extent, therefore, ruminants are grazing in previous non-agricultural areas, which should be preserved as nature reservoirs of diversity, CO_2 sequestration, eco-tourism, etc.

An important advantage of the Argentinean agri-food system is the enormous crop production, and vegetable food processing for the domestic and foreign markets. These activities generate considerable amounts of crop by-products, food industry by-products and other residues, most of which constitutes a valuable source of animal feed that is far from fully exploited.

Still nowadays the use of by-products as feed is not economically advantageous for most animal producers, since there are cheaper products available with equal or higher nutritive value than these by-products. However it seems that the more expensive option will be to produce feed products, and higher the use of these by-products as feed will be in the future.

5.4. The ALBIO model adaptability

As a tool is designed, tested and used, it will be improved during the learning process of users and designers if it helps them with their work. Therefore we consider it relevant to mention the main weaknesses and strengths found in the ALBIO model when doing our study, as a contribution to improving this IE tool.

5.4.1. Weaknesses

1) Alcoholic beverages are simplified as beer equivalent. Even though this sub-system does not appropriate considerable amount of phytomass, dividing alcoholic beverages into beer, wine, and white drinks, may give a more accurate representation of these flows. 2) Food residues are not possible to assign as feed other than the pig sub-system, however ruminants and chicken sub-systems may in some cases use food residues as feed. 3) Making a separate analysis of milk fates, may contribute to find out, amount of whey produced and as a consequence, the probable amount assigned to feed animals. 4) There could be an animal sub-system, which represent all other animal sub-systems not included as a specific sub-system. This could include rabbits, game, horses, and other animal meats. 5) It is not very clear where food industry losses are represented. Losses of vegetable processing are included in the ALBIO model, however no accounting of processing food losses exists, and these losses may be considerable in some industry. Meat processing, production of dairy, bakery, sweets, products, etc, losses may reach 10% of DM. 6) No all by-products are possible to allocate to all animal sub-system as feed. Since they exist in the model, they should be possible to allocate them as part of all animal sub-system feed mixes.

5.4.2. Strengths

1) The ALBIO model is an excellent tool to take good pictures of a particular food system. Not many countries may have their agri-food system under control from cradle to grave. The model offers a good starting point to integrate dispersed knowledge, information and data in a whole unique Balanced Scorecard[144]. 2) It is a good tool to examine the diversity of official institutions data types and data gaps regarding agriculture, food processing, and food distribution activities. 3) It offers the possibility to integrate phytomass generation with food intake. This means that as an IE tool, it allows system perspective analysis. 4) It works with a holistic point of view. That is using interdisciplinary approach. It contemplates nutrition, logistic, food production and agriculture variables. 5) It allows phytomass appropriation comparison of different food products. That is, to start thinking what does 200grs of beef or salad on a plate means in terms of phytomass

[144] A Balanced Scorecard is a management system (not only a measurement system) that enables organizations to clarify their vision and strategy and translate them into action.

appropriation, how they complement each other and how they may compete for the use of land. 6) It allows comparison of different food product efficiencies. That is, we can know, differences in overall efficiency among pig-meat poultry meat production, and we can compare them with other countries or regions, to see relative efficiencies. 7) It allows comparison of different efficiencies along the food chain. That is, if we are not doing well when producing a certain food-type commodity, where shall we put the effort to achieve an overall efficiency? 8) In addition to this, the ALBIO model concepts, offer the possibility to statistics organizations to use such a tool to see consistency of published data.

5.5. Data sources

In this sub-section we discuss accuracy and variations among data sources, as well as inconveniences in data collection and homogenization. We also put forward some recommendations of action to be taken in the monitoring of the agri-food system.

5.5.1. Accuracy of data sources

As described in section 3, this study relied on a number of major data sources. When data differed between sources, priority was given to local data. SAGPyA has valuable data on total production and yields of different crops, therefore these data were used for matching outputs. For pastured land by ruminants, such as permanent pastures, cropland and non-agricultural land data from CNA02 was used.

Data on food end-use, total population, crops used as feed, international trade, crop yields, etc was taken from FAOSTAT. We consider FAOSTAT data to be reasonably accurate for the purpose of this study. However, other local sources were needed to compare the information. It is important to mention the occasional low accuracy of FAOSTAT data.

Data sources for vegetable conversion efficiencies values were producer union statistics. This data could be considered accurate, since good information is available regarding this industry-type.

For slaughtered animal, ONCCA and SENASA data were used as guideline values. However, data on slaughter live weight by animal categories for livestock other than cattle were not available, so other information sources were used instead. Therefore sheep and goats values might not be as accurate as in the case of cattle sub-systems.

Harvest index data are considered accurate enough for most crops, with the exception of starchy roots for which harvest index data does not correspond to local data sources.

5.5.2. Trends since the year 2003

Economic and social activities change over time. Therefore it might be inferred that the results of this study are not up to date. The ideal tool would be such that allowed monitoring in real time, allowing instant modification of unwanted results in the environment, economy and social activities.

Since this is not possible, we will discuss here main important tendencies and changes since the analyzed period, i.e. the year 2003. That is, what would be results of this study if it was done with 2006 year data? Although it is not possible to answer this quantitatively, it is possible to describe main changes and tendencies of the agri-food system.

1) Continuous *expansion of agriculture borders* to less productive land, driven by increasing cropland area and re-location of cattle in lower productivity lands. This is possible because of technology improvement, crops genetic characteristics improvement, and increased use of fertilizers, pesticides, land irrigation, etc.
2) *Intensification of beef cattle* production. During the 90s there was a considerable increase in feeder steer/heifers in lots. Nowadays this tendency still exists, even though its share compared to the traditional method of feeding cattle on permanent pasture is still not significant.
3) *Increasing production of chicken and pig meat*. Even though there was a recovery of the cattle meat consumption per capita, the long term tendency is decreasing, and increasing other meat-types consumption.
4) *Increasing* crops *exports*, vegetable and animal products and by-products, as a consequence of favorable international prices.
5) *Continuing increase of crop yields*, especially of oil crops and cereals, as consequence of technology improvements and more inputs to the agriculture system.
6) *Continuing increased share of soybean* in the cropland surface. Soybean is Argentina's main crop and agricultural export product, and its expansion continues. During the year 2002/2003 12.6 million ha was sown, and for the period 2006/2007 this area sown is expected to be 16 million ha. There is a clear tendency forwards increased mono-cropping in the country. For the period under analysis 45% of the land surface sown with crops was soybean crops. Nowadays the share is considerably larger.
7) With the increasing price of *maize*, these crops *may gain back ground* in the Argentinean crop mix. This means that wheat crop, which contributes the biggest share of calories to the medium diet, may be missing in the share in the total crop production.
8) In 2005 the *Bio-fuels law*, which regulates production, trade and consumption of these fuels, was passed. In the local market, it binds a mix of petrol and bio-fuel for near future consumption. This new scenario combined with potential exports of these fuel-types, *will increase bio-fuel crops considerably*. Therefore this new demand will also involve the use of actual permanent pasture, not suitable for annual field crops, to produce a soybean which is resistant to different soil and climate conditions.

5.5.3. Data and information improvement

There is a need to improve the understanding of the agri-food system as a whole. It is not possible to take adequate decisions, if we do not know what impact they have on the food chain. There are plenty of institutions which collect and publish data and information. Frequently, however, public data are published with particular aims, with short time perspective, and many times with data gaps and lack of intra and inter-institutional coordination among public and private institutions. Actions suggested to address these issues include:

1) *To cover major information gaps*, which public institutions are not doing at the moment; to be able to analyze the agri-food system as a whole[145].
2) *To transform data into information*, with the purpose of informing the public, researchers, and decision makers. In this study we have converted the available data into information. However it should be done in a systematic manner and within an inter-institutional context.
3) *To homogenize the methodology of data collection* from public institutions. Data needs to be collected and compiled considering particular aims, and as part of a national contribution to the agri-food system. It is important to guarantee that individual efforts in data collection contribute to a comprehensive understanding of the country whole agri-food system.
4) *To articulate intra and inter institutional information needs.* To avoid duplication of work and missed information (e.g. data not available for the public), and cover interdisciplinary planning in the economic, social, nutritional and environmental fields.
5) *To predict behavior* of the system in the future under certain conditions. This may be done trough scenarios, which could contribute to prediction of possible changes in agri-food system if certain efficiencies, volumes and food type production are modified.

The agri-food system not only affects people's nutrition and health, but economic, social, and environmental relations as well. Therefore its holistic understanding should be of public concern. That is, food and energy organizations, governmental institutions and universities should be the main drivers behind initiatives proposed.
In what way could public programs and institutions take the recommendations of this study? Could these institutions work on an inter-institutional planning? Could SAGPyA, INTA and INDEC produce this information? Could ONCCA, SENASA[146], FAO, Producer Unions, MSAL, and Energy Secretary[147] contribute to this proposal? Could PROSIGA[148] be the tool to broadcast the generated information?

[145] Data gaps are assumptions along the study which had to be taken from local academic studies.
[146] ONCCA and SENASA, should be included in this matching data labor.
[147] The Energy Secretary main aims are the production, proposals and executions of national energy policies; to study and analyze the behavior of the energy markets, and to control and supervise the rational use of energy sources and protection of the environment.
[148] PROSIGA is a national program of geographic information. One of the principal aims of this program is to facilitate the availability of geographic information for the public, and to reduce overlapping efforts when generating information regarding development and planning, security, non-renewable and renewable energy, urban and rural land registry, agriculture, industry, education, and base information.

6. End-use characteristics

Because we consider this topic relevant when studying the food chain, though not being the principal aim of the study, we briefly describe the end-use situation at consumer level in this section. We describe how food is distributed among population and add minor comments about the nutritional state of people. Since this section is not related to modeling, the reader may omit the section and go to the Conclusions and future outlook section, on page 92.

6.1. Diet habits in the country

Even though the improvement in food production during last 300 years is a scientific fact, we still do not eat properly. Lobbies and market power dominate our tastes and dietary habits. According to Aguirre (2000) one the most important consequences of the recent intensification of capitalist production in relation to our diet, is that food production has been converted into production of benefits and not of food….. We do not eat what we want but we eat what market wants to sell us, and market does not sell what feeds us but what produce profits.

Two factors are the most important to decide the everyday diet, the available money and knowledge of a good meal. Diet habits are changing, everyday more people eat out of home, at least once a day. Outside of home, people normally eat less fruits, vegetables and natural products. The food is more elaborate, saltier, fried and sauce, and includes more animal fat and simple carbohydrates.

Our daily life is changing our diet habits. In Argentinean cities, people do not have time to have lunch. Therefore they eat what they can, with the few minutes they have for that. The popular phrase “breakfast like a king, lunch like a prince and dine like a pauper” is not applicable to most people. Diets are changing to involve fast food such as sandwiches, hot dogs, pies, pizzas and burgers.

In urban societies the group-eating conditions are changing. As well according to Aguirre (2000) the act of eating today, in a globalized world, moves further away from ”collective eating” every day. Even worse, it is more of an individual and wandering act: “The urban way of eating is an individual nutritional act, a short and messy nibble or the kingdom of snacks”.

That is, it seems that changes in our daily habits are occurring, but we have not stopped to think about them. Should we change our diet habits? Changing food choice and dietary habits may require breaking behavior patterns. Are we willing to do these changes?

6.2. Nutrition among the population

Even though there is enough food production in the country to feed the nutrition needs of the population (8 times over), according to FAO (2001) there are deficiencies in energy and in micronutrients among the lower-income sectors. There is a need for redistribution measures and a food program aiming at the most vulnerable groups, as well as measures to promote appropriate proper dietary habits to diminish the amount of overweight people. The nutritional situation in Argentina is diverse; Alvarez *et al.* (2000, p. 238) quotes a study stating that in the country chronic and severe undernourishment coexist with the overweight, obesity, and hidden undernourishment (specific nutrients deficiency in apparent healthy people).

If we observe the unequal distribution in the country, we can see that appropriation of food-types is fully disproportional. According to Aguirre (2000) when we consider food consumption according to incomes we see that richer people eat fruit, vegetables, white meats, dairy products (especially cheese), candies and drinks (sodas and alcohol) while the poorest, only exceed in consumption of bread, dry pasta, and potatoes.

Unequal consumption by gender is a subject to take note of as well. Food appropriation and distribution in house families, often shows the explicit or implicit inequalities. According to Aguirre (2000) the food distribution is also unequal inside of each family house. Confronting the hegemonic group of men - adults - employed, women learn to auto exclude themselves, and children and elderly get less quantities and/or less quality. The distribution is so irrational that in this era of abundance, sub nutritional and over nutritional public health problems are overlapped.

These are important topics to tackle. Government and civil organizations work on these social problems. They seem to be considerable smaller with the actual positive economic expansion, however to eliminate all these unnecessary but still remaining social problems is an obligation.

6.3. Governments and civil organizations

There are many national, regional and municipal programs promoting and contributing for adequate nutrition. According to Britos et al. (2005) there are six nutritional national programs. During 2003 law 25724 created the Feed and Nutritional National Program (PNSA), to guarantee nutritional requirements to children up to 14 years old, pregnant women, the handicapped and elderly people older than 70 years on adverse economic situation. During 2006 the Nutritional and Feed Educational National Program was created, oriented to improve the nutritional quality of the population, through information diffusion.

NGO’s have a role in society as well. They are involved in activities of food collection, food distribution and assistance, educational programs, and even promoting consumption of certain food-type. Many NGOs collect and re-distribute food in the country, contributing to an adequate nutrition for a considerable number of people with inadequate incomes. Recovery systems or collection of food happens in different stages of the food Chain[149]: primary producers (farms), food industry, vegetables and fruit central markets, wholesalers, retailers and consumers. Some of these organizations work with welfare, but others make action and articulation networks among potential beneficiaries and donors. Their missions are to eliminate hunger by developing national food bank networks within the country.

Regarding promotion of different food-type consumption, there is only one official institution. That is the IPCVA is an official institution created to consolidate and improve the image of Argentinean beef inside and outside the country. However there has not been action yet from government to create similar institutions promoting vegetables, fruits, and more energy efficient meat-types consumption such as poultry and pig.

Some initiatives can be seen from civil organizations[150] promoting consumption of other meat-types, fruits and vegetables. However, isolated initiatives and lack of global organization show that it is necessary to have a national food program working with production and consumption needs. A national integrated and multidisciplinary program is the only way to achieve an agri-food system in equilibrium and in accordance with the environment, the economic development, and population nutrient requirements.

[149] Law 25989 was passed in the National Congress and later partially canceled. It promoted the better use of innocuous food, which can not be sold because of manufacturing faults of packaging, overproduction or/and out of date.
[150] “5 al día” is an NGO promoting consumption of vegetables and fruit among the population.

7. Conclusions and future outlook

Vegetables, fruits, and converted vegetable foods contribute significantly to improve the overall efficiency of the agri-food system.

Animal food-types have the lowest efficiencies of the agri-food system. However, there are considerable differences among them. Dairy products are the most efficient, then come poultry and pig products, and with much lower overall efficiencies come beef cattle, sheep and goats sub-systems.

The Argentinean average diet has a considerable share of animal food-types, and relies mainly on cattle meat. This type of diet makes the overall efficiency of the agri-food system considerable low.

The goats sub-system has the lowest overall efficiency compared to any other animal. Even its overall phytomass appropriation is not considerable, to avoid unnecessary environmental impact, the stock of animals in this sub-system should not be increased further and efficiencies should be increased considerably.

Crops and cattle sub-systems sometimes compete for the same feed sources and fail to use conservation agriculture. However, farming practices that successfully integrate crop and livestock enterprises stand to gain from many potential synergies that directly improve efficiencies.

Sometimes, ruminant sub-systems inefficiencies may not be relevant as long as these animals are grass-feed on land not usable for crop production (i.e. Patagonia, Monte Árido, Chaco Húmedo ERs), or raised primarily on crop by-products that are indigestible and unpalatable to non-ruminant species.

The crop by-product utilization still is very low. Their potential utilization is much higher than actual. Therefore, their utilization as material and energy sources could be increased considerably, and at the same time increasing its share in ruminant sub-systems diets can improve efficiencies of the agri-food system.

The lowest efficiencies for animal sub-systems are conversion efficiencies. However it seems that potential biggest improvements are in animal feed utilization efficiencies. That is, there are big opportunities to increase pasture utilizations in all ruminant sub-systems.

Food and bio-energy production may compete in the near future for the land. But even sometimes the food/bio-energy integration may imply competition of resources in the agriculture system, its combination offers at the same time great potential of synergies and complementation.

Losses at the end of the system, that is, losses close to the final intake or ingestion, represent the highest avoidable phytomass appropriation. A unit of food not wasted at the end of the food system, could save considerable amounts of phytomass appropriation.

Future outlook

Priorities given to animal sub-systems development for internal consumption should be promoted with due consideration. That is, if changes in eating habits are done in the right direction may have big positive impact on the overall efficiency of the agri-food system and boost exportable amounts of biomass commodities.

Human nutrition, laws and programs contribute to improve people's quality of life and to develop and improve the economic activity of the agri-food system. However, Argentina needs a national strategic plan that encompasses environmental, commercial and nutritional requirements.

When eating, we not only incorporate nutritional substances which maintain our organic equilibrium, but also attach symbolic meaning to food, as social individuals. That is, the act of eating involves habits, social relations, status, health, likes, purchasing power, etc. Therefore, if we pretend to modify eating habits, the entire society should be involved in this discussion.

Many analyses for potential improvements in the agri-food system are left behind this study as open questions. Those topics are 1) the potential land from actual agriculture that could be used for bio-energy crops is a topic that should be studied further. 2) At the same time, it would be important to study the potential land freed if changing the average diet (maybe substituting meat-types?). 3) As well, the potential productivity increases in livestock production and the potential contribution to improve the overall efficiency of the agri-food system is important to know. 4) And least but not last, the potential decrease losses of end-use food to enhance the efficiency of the system, is another important topic to that should be studied deeply.

The land and biomass flows model of Argentinean agri-food system is hoped to bring a system perspective discussion. The possible applications, shortcomings and the development needs of the analysis will be reveled after the study has been review.

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National organizations

SAGPyA - National Secretariat for Agriculture, Livestock, Fisheries and Food. [online]. Available from: www.sagpya.mecon.gov.ar

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Agricultural and food industry unions

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8.3. Personal communication

Cattle

Peuser, Ricardo. Cátedra de Nutrición Bovina. UNC
Andreo, Norberto. Ganado Lechero, INTA Rafaela
Colombatto, Darío. Cátedra Bovinos de Carne. UBA
Aello, Mario and Di Marco, Oscar. INTA Balcarce

Sheep and Goats

De Gea, Ginés. Cátedra Ovinos y Caprinos, UNRC.
Pondé, Marcelo. Sector Caprino. SAGPyA
Macario. Frigorífico San Javier. Villa Dolores
Lynch, Gloria and Simonetti, Laura. Cátedra Ovinos. UNLZ

Pig

Guerra, Carlos. Sector Porcino, INTA Pergamino
Dimeglio, Sergio and Arrieta, José Carlos. Biofarma S.A. Company

Poultry

Lámelas, Karina. Sector Aviar, SAGPyA
Micheluzzi, Luis. AVIMETRIA Company
Bina, José A. Agro Imperio S.R.L. Company

Crops and by-products

Garcia Buró, Fernando. Equidiet Company.
Miralles, Daniel. Cátedra Cerealicultura. UBA
Haro, Ricardo. INTA Manfredi.
Ullivarri, Enrique. INTA Famaillá

Pastures and Forage

Rodríguez, Adriana. Cátedra Forrajicultura. UBA
Clemente, Gustavo. Private Consulting. Villa María.

Fish

Torre, Julio. Revista Redes Company
Rodríguez, Karina. Moliendas del Sur Company

9. Appendix A

Acronyms of concepts and units

DE	Digestible Energy
DM	Dry Matter
GE	Gross Energy
HHV	Higher Heating Value
NE	Net Energy
NE_g	Net Energy for growth
NE_l	Net Energy for lactation
NE_m	Net Energy for maintenance
NPP	Net primary production
ME	Metabolizable Energy
ER	Eco-Region
ha	Hectare
IE	Industrial Ecology
MFA	Material Flow Analysis
APNPP	Above-ground Phytomass Net Primary Productivity

Acronyms of Institutions

ALBIO	Agriculture Land Use and Biomass Flows
CNA02	2002 National Agricultural Census
FAO	Food and Agriculture Organization of the United Nations
FAOSTAT	FAO Statistical Database
FBS	Food Balance Sheet
IICA	Inter-American Institute for Cooperation on Agriculture
INDEC	National Institute of Statistics and Censuses
INTA	National Institute for Agricultural Technology
IPCVA	Argentine Beef Promotion Institute
NRC	National Research Council (U.S.)
ONCCA	National Livestock Trade Control Bureau
PRECOP	National Project to Increase Harvest and Post-Harvest Efficiency
SAGPyA	National Secretariat for Agriculture, Livestock, Fisheries and Food
SENASA	Animal and Plant Health Service
UBA	Buenos Aires National University
UNC	Córdoba National University
UNL	Luján National University
UNLZ	Lomas de Zamora National University
UNRC	Río Cuarto National University

Notes

1 Giga gram [Gg] = 1×10^9 grams = 1,000 metric tons
1 Terra gram [Tg] = 1×10^{12} grams
1 Peta joule [PJ] = 1×10^{15} joules
1 Exa joule [EJ] = 1×10^{18} joules
1 Calorie [Cal] = 4.184 Joules

10. Appendix B

Extra tables

Eco-Region	Total	Beef cattle cows and calves	Heifer & steer before feeder	Pasture feeder		Feed-lot	Dairy cattle	Cotta-ge	No specia-lized cattle
				With feed supplement	Without feed supplement				
Chaco Húmedo	**14%**	51.2%	9.8%	3.7%	10.2%	0.6%	4.1%	0.2%	20.1%
Chaco Seco	**0.8%**	9.6%	1.9%	1.1%	3.2%	0.1%	0.1%	0.4%	83.8%
Mesopotamia	**12%**	71.1%	8.3%	2.6%	6.4%	0.4%	0.6%	0.5%	10.2%
Monte Arido	**9.3%**	64.3%	10.2%	2.8%	5.1%	1.4%	1.0%	0.7%	14.5%
Oásis Cuyano	**0.6%**	65.6%	4.5%	1.4%	1.7%	0.6%	0.8%	0.3%	25.1%
Pampeana	**60.%**	50.0%	10.0%	13.5%	12.6%	1.3%	11.%	0.8%	0.9%
Patagonia	**1.4%**	71.4%	8.0%	1.4%	3.0%	0.8%	0.6%	0.2%	14.6%
Puna	**0.0%**	0.6%	0.5%	0.0%	2.7%	0.0%	0.3%	0.0%	95.8%
Subt del Norte	**0.9%**	39.4%	6.1%	6.4%	7.3%	4.5%	4.0%	0.1%	32.1%
Valles del Norte	**0.3%**	24.4%	3.0%	4.0%	4.7%	1.0%	4.4%	0.6%	57.7%
Valles Patag	**0.4%**	72.1%	2.2%	1.0%	4.1%	0.0%	0.2%	0.0%	20.4%
TOTAL	**100%**	**54.0%**	**9.6%**	**9.3%**	**10.4%**	**1.1%**	**7.4%**	**0.6%**	**7.5%**

Table 28. Cattle stock composition by ER and feed category. CNA02.

Eco-Region	Stock distribution
Puna	3.5%
Valles del NOA	2.0%
Subtropical del NOA	0.4%
Chaco Seco	0.7%
Monte Arido	3.3%
Chaco Humedo	1.2%
Mesopotamia	9.4%
Patagonia	65.4%
Pampeana	13.5%
Oasis Cuyano	0.3%
Valles Patagonicos	0.3%

Table 29. Sheep stock by ER. CNA02.

Eco-Region	Stock distribution
Puna	3,3%
Valles del NOA	10%
Subtropical del NOA	1,5%
Chaco Seco	7,7%
Monte Arido	37%
Chaco Humedo	6,5%
Mesopotamia	0,5%
Patagonia	22%
Pampeana	0,7%
Oasis Cuyano	8,4%
Valles Patagonicos	2,1%

Table 30. Goats stock by ER. CNA02

Eco Region	Cropland Pasture yields [ton DM/ha year]	Cropland Pasture [ha]	Permanent Pasture yields [ton DM/ha year]	Permanent Pasture [ha]	Non-agricultural land [ha]
Chaco Húmedo	4	6%	3	9%	16.1%
Chaco Seco	1.5	0.2%	2	0.4%	7%
Mesopotamia	5	2%	5	7.5%	5.4%
Monte Arido	1.5	14.7%	1.8	7.4%	46.7%
Oásis Cuyano	5.5	0.1%	0.9	3.2%	6.2%
Pampeana	15	75%	7	15.7%	6.9%
Patagonia	1	0.5%	0.55	52%	4.8%
Puna	-	-	0.2	0.4%	-
Subtropical del Norte	6.5	1.1%	1	0.7%	3.5%
Valles del Norte	1	0.3%	0.5	0.3%	2.4%
Valles Patagónicos	6	0.1%	0.9	3.4%	1%
Average	**11.9**	**100%**	**2.24**	**100%**	**100%**

Table 31. Cropland and permanent Pastures yields, expressed in DM tons per ha & year.

Productivity Parameters	**Units**	Milk Cattle	Beef Cattle	Sheep	Goats	Pig	Meat-type chicken	Leg.-type chicken
Female reproducer mature live weight	[kg]	550	431	40	40	270	3.2	1.6
Reproducer mortality	[dead/stock]	0.02	0.05	0.08	0.09	0.09	0.10	0.09
Milk or egg yield	[kg/producer]	4098	-	-	-	-	-	13.7
Weaning / hatching rate	[weaned or hatched/repr.]	0.72	0.62	0.68	0.79	18	158	60
Birth weight	[kg]	39	33	3.2	3.2	1.3	0.04	0.04
Male reproducer in stock	[male/female in stock]	0.025	0.050	0.055	0.050	-	-	-
Flow out female reproducer	[slaughtered/stock]	0.21	0.10	0.10	0.10	0.35	1.20	-
Replacement age at first birth	[months or days]	33	33	24	15	340	168	126
Producer mortality	[number dead/born]	0.02	0.02	0.08	0.09	0.06	0.07	0.09
Female producer live weight at slaug.	[kg]	284	286	20	9	-	-	1.6
Male producer live weight at slaug.	[kg]	378	420	22	10	99	2.67	-
Male producer growth rate	[weight gain/day]	0.45	0.50	0.20	0.025	0.50	0.05	-
Female producer growth rate	[weight gain/day]	0.41	0.45	0.18	0.023	-	-	-

Table 32. Assumed productivity parameters in animal sub-systems. All rates if not specified are in years.