Learnings from an FAO-led international process to develop LCA guidelines for small ruminants: A LEAP Partnership initiative

Stewart.Ledgard[1,*], Beverley Henry[2], Armelle Gac[3], Marc Benoit[4], Canagasaby Devendra[5], Chris Lloyd[6], Hans-Peter Zerfas[7], Jean-Baptiste Dollé[8], Felix Teillard[9,10], Carolyn Opio[9], Camillo De Camillis[9], Pierre Gerber[9]

[1] AgResearch Ruakura Research Centre, Hamilton, New Zealand
[2] Queensland University of Technology, Brisbane, Australia
[3] Institut de l'Elevage, Le Rheu, France
[4] INRA, UMR1213 Herbivores, F-63122 Saint-Genès-Champanelle, France
[5] Consultant, Malaysia
[6] EBLEX, Warwickshire, England
[7] World Vision, Friedrichsdorf, Germany
[8] Institut de l'Elevage, St Laurent Blangy, France
[9] Food and Agriculture Organization of the United Nations, Rome, Italy
[10] INRA-AgroParisTech, UMR 1048 SAD APT, F-75005 Paris, France
[*] Corresponding author. E-mail: *stewart.ledgard@agresearch.co.nz*

ABSTRACT

Methodology and guidelines for quantifying greenhouse gas (GHG) emissions and fossil fuel demand from sheep and goat supply chains covering the system boundary of the cradle-to-primary-processing-gate were developed by an international technical group. Key learnings included the need to recognize and account for 1) the global diversity of small ruminant production and processing systems, 2) the potential for limited data availability, and 3) several main areas of methodology that have potential to change the final results. Two critical areas of Life Cycle Assessment (LCA) based methodology identified were the importance of determining feed requirements by animals and the methods for handling multi-functional processes including allocation. On-farm, biophysical allocation based on relative feed requirements was recommended for allocation between animal species sharing the same feed sources and for allocation between meat, milk and/or fiber. However, sensitivity analysis of different allocation methods should be carried out and results presented to illustrate the effects on results.

Keywords: greenhouse gases, goats, international, methodology, sheep

1. Introduction

Livestock have been identified as being major contributors to resource use and environmental impacts at a global scale (e.g. Gerber et al. 2013; Steinfeld et al. 2006). Small ruminants (e.g. sheep and goats) are a relatively small component of the total livestock sector but are of global importance because they cover a wide diversity of systems across an enormous range of geographical regions that provide a variety of products and functions. In 2011, sheep and goats produced more than 5 million tonnes of meat and 24 million tonnes of milk globally and production has increased by 1.7% and 1.3% per year, respectively, during the past 20 years (FAOSTAT, 2014). This increase was driven mainly by developing countries in Africa and Asia, although Oceania (mainly for meat) and Europe still contribute significantly to production. Production systems can vary from intensive systems, where animals are partially or predominantly housed, to extensive systems which rely on grazing and native forages, and transhumance systems that involve large flock movements. Products are not restricted to meat and milk; sheep are also valued for their wool (more than 2 million tonnes of greasy wool was produced globally in 2011), and goats for their mohair and cashmere. Small ruminants also play a crucial role in small-scale, rural and family-based production systems by sustaining livelihoods, contributing to food security and nutrition, providing a way to store and manage wealth and supporting ecosystem services.

Of the range of environmental impacts from livestock systems, climate change associated with greenhouse gas (GHG) emissions has received the most attention during the past decade. This has resulted in efforts to support decision-making of purchases by consumers by making them aware of GHG emissions linked to products they eat through environmental labelling of products (e.g. Tescos scheme in the United Kingdom and one of the indicators in the pending Grenelle scheme in France). Labelling focused on the carbon footprint (i.e. total GHG emissions expressed on a CO_2–equivalent basis) throughout all stages of production and provision of products to consumers has generally involved the use of a Life Cycle Assessment (LCA) approach.

Similarly, an array of environmental assessment methods have been set up in support of product-based environmental performance schemes for business-to-business communication (e.g. environmental product declaration schemes), and of environmental improvement reporting systems (e.g. incentives linked to GHG emission mitigation options). Furthermore, other LCA-based approaches are being examined by some governments to monitor the environmental footprint of the economy and set environmental policy priorities at the sector level accordingly (e.g. the life-cycle based indicators developed by the European Commission).

Given such proliferation, it is desirable that an internationally-acceptable common methodology is used so that products can be assessed on a similar basis. Common and robust methodology tailored to the specific nature of small ruminant supply chains will also enable various stakeholders to identify hotspots and opportunities to reduce environmental impacts. Some sectors have started to work together to agree on a methodology, which has typically been based on use of an LCA approach (e.g. for milk products by the dairy sector; IDF 2010). Similarly, initial work on a draft methodology for lamb meat was initiated by Beef+LambNZ and the International Meat Secretariat. Recently, the Food and Agriculture Organization of the United Nations (FAO) has initiated a broad process to develop harmonized international methodologies and guidelines to assess the environmental performance of livestock supply chains. This resulted in the Livestock Environmental Assessment and Performance (LEAP) Partnership, which is a multi-stakeholder initiative whose goal is to improve the environmental sustainability of the livestock sector through better metrics and data (LEAP 2014a). The LEAP Partnership comprises a large range of government, industry and civil society organizations. The three groups are represented at a Steering Committee, while the Guidelines are primarily developed by Technical Advisory Groups (TAGs) of international experts with experience in LCA, GHG emissions and livestock systems. One of such TAGs was established and has been active over the past year in developing guidelines for assessing GHG emissions and fossil fuel demand for the small ruminant sectors. This paper reports on aspects of methodology development of the small ruminant guidelines and key learnings from it. In March 2014, the draft guidelines for small ruminant supply chains (LEAP 2014b), poultry supply chains (LEAP 2014c) and animal feeds (LEAP 2014d) were released for public review by the FAO, with the intention of revising them and producing a final set of guidelines in late-2014.

2. Methodology

The first key role of the TAG was to define the scope of the methodology. It was decided to limit the small ruminants covered by the guidelines to goats and sheep due to their significance and data availability. However, the principles developed could be applied to other small ruminant species such as alpaca and deer. It was recognized that globally there are a very wide range of products produced from small ruminants with the major ones being meat, milk and fiber. It was decided to confine the system boundary covered by the guidelines to the cradle-to-primary-processing gate (Figure 1), while recognizing that environmental communication and comparisons of products must be based on the full supply chain and, therefore, the importance of future development to extend the guidance to the full life cycle. The primary processing stage for each of the main products was selected as the end point for the guidelines since it is in common to most end products, whereas secondary processing stages can vary greatly depending on the final product(s) produced.

Separate guidelines were developed in parallel for the animal feed supply chain (LEAP 2014d) and these covered emissions from all aspects of feed production through to the animal's mouth, whether the feed was produced on the livestock farm or purchased. Thus, it was important to align the LEAP Animal Feed Guidelines with those on the small ruminants (see Figure 2). Relevant points of alignment to avoid double counting or missed processes include 1) manure leaving a farm for application to feed crops leaves the system boundary of the small ruminants as it is collected (i.e. collection and on-farm storage emissions belong to the small ruminant guidelines), while all subsequent emissions from transport and after application are associated with feed production, and 2) any emissions associated with feed wastage at the animal feeding step on farm are accounted for in the small ruminant guidelines.

The main impact category covered by the small ruminant guidelines is climate change, estimated from the GHG emissions and expressed as CO_2-equivalents. Previous work done on guidelines for animal feeds provided the Feed TAG with the opportunity to expand the scope of the LEAP Animal Feed Guidelines to include other impact categories of eutrophication, acidification and land occupation. The GHG emissions in the small ruminant guidelines include methane (CH_4) emissions from rumen enteric fermentation and from animal dung and manure, nitrous oxide emissions (N_2O) from animal excreta deposited directly on grazing/browsing land and from manure collection and storage on-farm, and energy-related inputs from animal management, water supply and for primary processing (Figure 2). It also includes emissions from animal transportation, and primary processing emissions such as from the use of energy, consumables, refrigeration and wastes and waste-water processing.

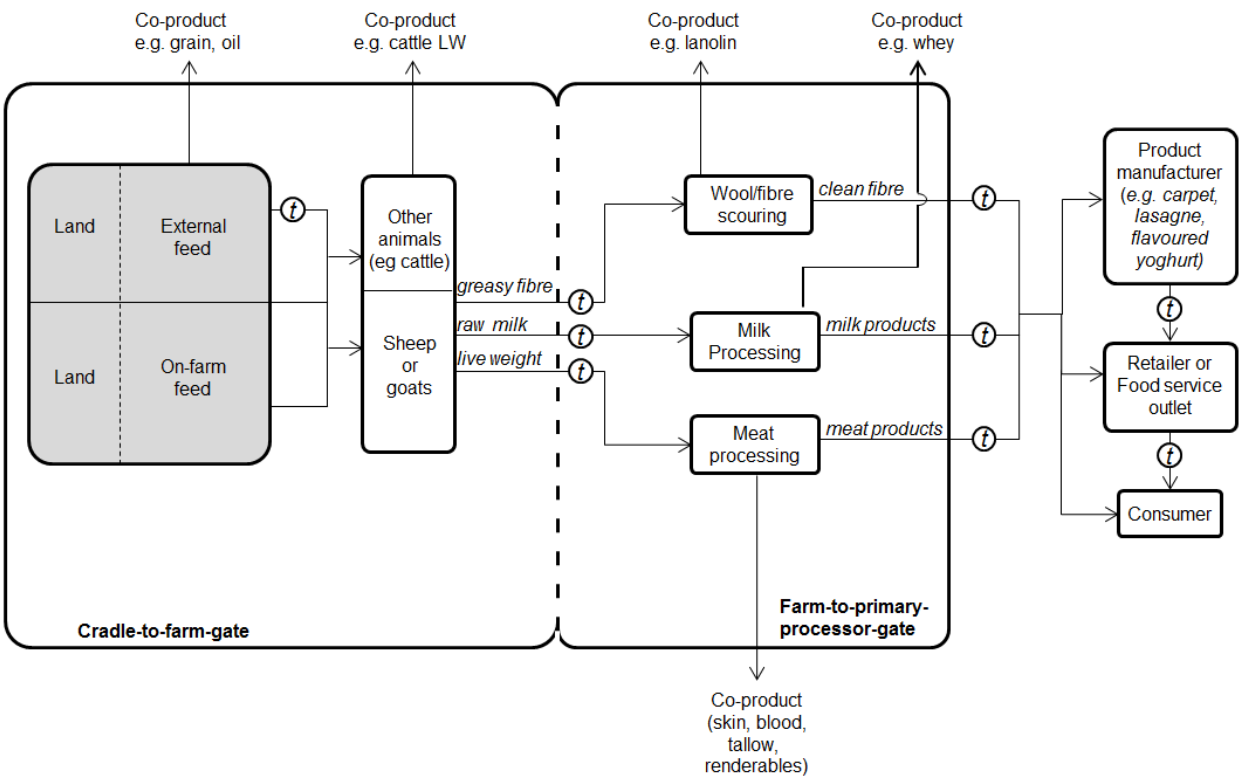

Figure 1. System boundary diagram for the cradle-to-primary-processing-gate for sheep and goat supply chains covering the three main products of fiber, milk and meat. The land and feed (inner shaded left box) is covered in the LEAP Animal Feeds Guidelines (LEAP 2014d). The ⓣ symbols refer to the main transportation stages.

The unit of analysis depends on the relevant stages of the life cycle covered. In view of the significance of the cradle-to-farm-gate stage, and that many published studies are limited to this component of the life cycle, these units have been expressed for this stage as well as for the cradle-to-primary-processing gate (Table 1). The equation for energy-corrected milk (ECM) is based on that from the IDF (2010) for dairy cow milk, to enable comparison between and within animal species, as:

$$\text{kg ECM} = \text{kg milk} \times (0.1226 \times \text{fat\%} + 0.0776 \times \text{true-protein\%} + 0.0621 \times \text{lactose\%})$$

Table 1. Recommended units of analysis for the three different main product types from small ruminants according to whether it is leaving the farm or primary product processing gate.

Main product type	**Cradle-to-farm-gate**	**Cradle to primary-processing-gate**
Meat	Live-weight (kg)	Meat product(s) (kg)
Fiber	Greasy weight (kg)	Clean weight (kg)
Milk	Energy-Corrected-Milk (kg)	Milk product(s) (kg)

The TAG was composed of eight selected experts drawn from six countries. Their backgrounds and complementary knowledge of products, systems and regions, allowed them to understand and address different interest groups and so ensure credible representation. While the TAG leader had a key role in drafting the guidelines, workshops and other interactions allowed consensus to be reached within the whole group. Before their release for public review, draft guidelines were reviewed by the LEAP Steering Committee and three independent reviewers.

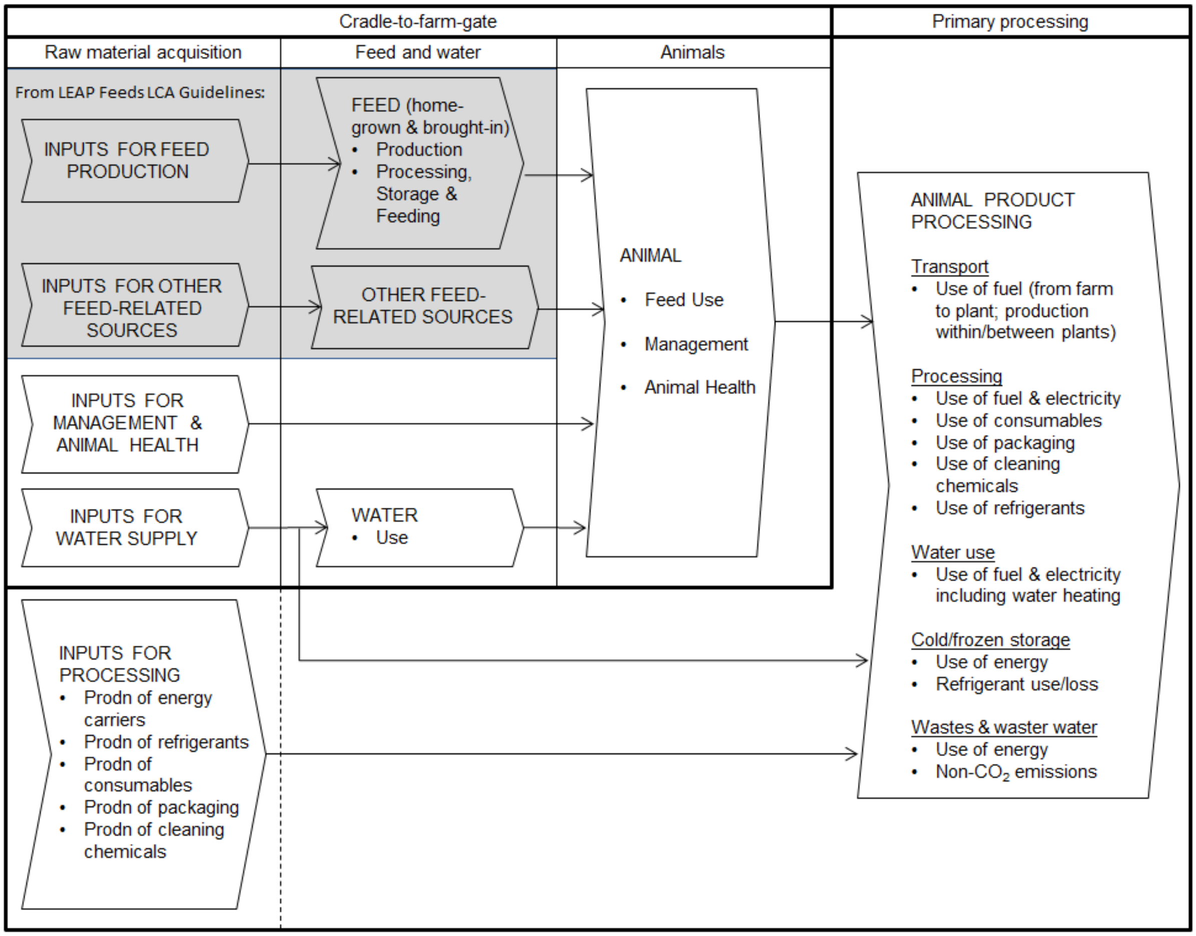

Figure 2. Processes that contribute to GHG emissions and fossil fuel demand within the system boundary of the cradle-to-primary-processing-gate for small ruminants. Note that the upper left shaded box refers to components covered by the LEAP Animal Feeds Guidelines (LEAP 2014d).

3. Results and Discussion

A methodology and guidelines for application were developed for determination of the GHG emissions and fossil energy demand from sheep or goat supply chains within the system boundary of the cradle-to-primary-processing-gate. The cradle-to-farm-gate stage was seen as being particularly important to cover in detail because of its significance to the whole life cycle. For example, Ledgard et al. (2011) evaluated the cradle-to-grave carbon footprint of lamb produced in New Zealand (NZ) and consumed in the United Kingdom and found that the cradle-to-farm-gate stage constituted 80% of total life cycle GHG emissions. The corresponding value for the primary meat processing stage was 3%.

Two areas of methodology identified as of key importance were 1) determining feed requirements by animals, and 2) the methods for handling multi-functional processes including allocation. These are discussed in the following sections.

3.1. Importance of determining feed requirements by animals

Within the cradle-to-farm-gate stage, the majority of GHG emissions from ruminant animals are determined by the amount of feed intake by animals, which is the main driver of enteric CH_4 emissions and of the amount of N excreted (the main source of N_2O emissions). Research in France and NZ (Gac et al. 2012; Ledgard et al. 2011) across diverse surveyed sheep farm systems showed that of total cradle-to-farm-gate GHG emissions, 53-73% were from enteric fermentation and 16-20% from excreta N_2O emissions. Thus, it was considered critical to obtain an accurate estimate of total feed intake and to use an IPCC tier-2 approach rather than a simple tier-1 approach. The latter is simply a constant value per animal and therefore would provide no opportunity to use the methodology to assess potential benefits from improved animal production and management practices.

In many small ruminant systems, much (or all) of the animal's time is spent grazing or browsing a range of forages. Thus, it is difficult to get a direct estimate of feed intake by primary data collection. Actual primary data on feed provided and consumed will often only be possible for the component of feed that might be stored on-farm or brought-in to the farm from an external source (e.g. concentrates). Consequently, an indirect modelling approach is required to calculate feed intake based on the energy requirements of animals. Most models used for calculation of feed requirements derive intake from the energy requirements for animal processes of growth, reproduction, fiber production, milk production, activity (i.e. grazing/walking) and maintenance (e.g. IPCC 2006; NRC 2007). The guidelines recommended that the choice of model/method should be based on a hierarchy of:

1. country-specific models used in the country National Greenhouse Gas Inventory;
2. other models that have been peer-reviewed and published that are appropriate to the region and country;
3. IPCC (2006) model;
4. IPCC default tier-1 values (this should be used as a last resort).

Associated data on the energy concentration of the feed(s) is required to convert energy intake by animals in feed(s) to dry matter intake. Again, this should be based on a hierarchy of: primary data for the specific feed type(s) where available; published values from the region or country for the specific feed type; or general published values (e.g. NRC 2007). Conversely, dry matter intake can be known or assessed from past research (from intake capacity by animals depending on level of productivity, e.g. as used by INRA, France) and energy intake can be derived from data on energy concentration of feeds.

Prior to calculating feed intake, the other critical aspect is to define the animal population and productivity over a representative one-year period. The animal population data must recognize the number of breeding animals (e.g. breeding ewes or does, rams or bucks, and the replacement breeding animals), as well as animals for production (e.g. surplus lambs or kids). This is illustrated for a simplified example of an animal population for a sheep farm system in Figure 3. From the base animal population data, an annual stock reconciliation needs to be derived that accounts for the time of lambing/kidding and time of sale of surplus animals. Ideally, a monthly or seasonal stock reconciliation would be used. The benefit of having a tier-2 methodology (using calculated energy requirements) and specific seasonal or monthly data is that the effects of improvement in animal productivity on reducing the carbon footprint of products can be determined. For example, achieving the final slaughter weight of lambs earlier results in a lower feed intake and the maintenance feed requirement is reduced relative to the feed needed to achieve a given level of animal production.

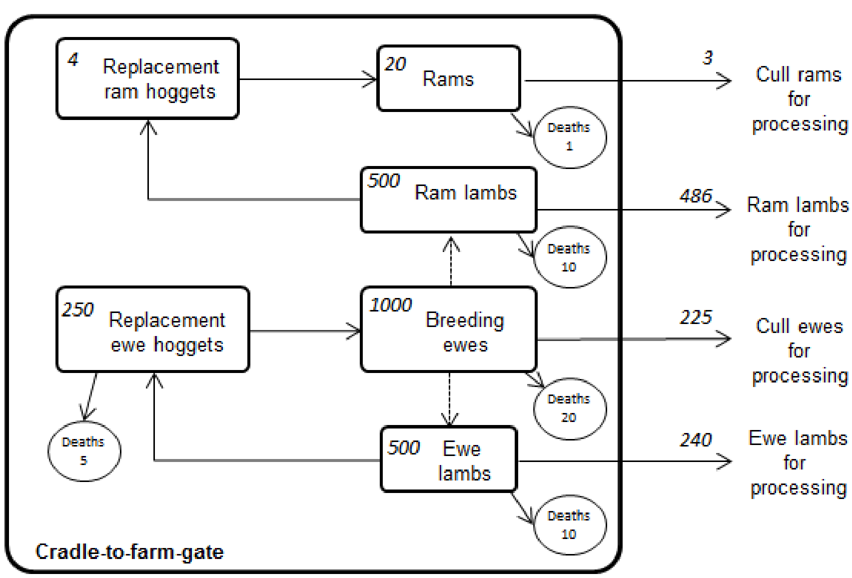

Figure 3: Simplified example of a sheep population illustrating relative numbers of breeding and replacement sheep on-farm and surplus sheep sold for meat processing (based on a breeding ewe flock of 1000, 100 percent lambing, 25 percent replacement rate, 2 percent death rate and first lambing at 2 years of age).

Calculation of animal productivity requires average data on male and female adult live-weight, live-weight of animal classes at slaughter, fiber production and milk production (for milking sheep or goats). Primary data on the animal population and productivity shall be used where possible.

3.2. Handling multi-functional processes including allocation of GHG emissions between co-products

There are a number of stages within the system boundary where multi-functional processes occur and where accounting for GHG emissions between different co-products is required (Figure 1). The ISO 14044 (2006) standard provided a hierarchy approach for accounting for co-products based on system separation wherever possible, followed by system expansion and then allocation options with an approach reflecting the underlying (bio)physical relationships between co-products being the preferred first option. As part of the LEAP process, a multi-functional output decision tree was developed (see LEAP 2014b,c,d) to further aid in selecting a system for handling co-products based on ISO 14044 (2006) and this was applied consistently across the small ruminant and poultry TAGs.

A summary of the recommended methods developed for handling co-products is given in Table 2, although it is also recommended that a sensitivity analysis involving several methods is applied to illustrate the effects of the choice of method used. Within the farm, there are two stages where choices relating to animal co-products may be required, i.e. for mixed species sharing the same feed resources, and for milk, meat and/or fiber production from sheep or goats (Figure 1). The preferred method for accounting for these multi-functional processes and co-products is firstly to separate activities related to the co-products where possible, and then to apply a biophysical approach based on energy intake from feed associated with the different animal species or co-products. This also recognizes that in ruminant livestock systems, the major determinant of GHG emissions within the farm stage is enteric CH_4 and excreta N_2O emissions, and the driver of these is feed intake (as noted in section 3.1).

Table 2. Recommended methods for dealing with multi-functional processes and allocation between co-products for the cradle-to-primary processing gate stages of the life cycle of small ruminant products

Source/stage of co-products	Recommended method*	Basis
Animal species (within farm)	1. Separate farm activities 2. Biophysical causality	First, separate the activities specific to an animal species and attribute the inputs/emissions accordingly. Then, determine emissions specific to feeds relating to the sheep or goats under study. If not possible and for remaining non-feed inputs, use biophysical allocation based on the proportion of total energy requirements for each of the different animal species.
Live-weight, fiber, milk for sheep or goats (at farm gate)	1. Separate activities 2. Biophysical causality	First, separate activities specific to products (e.g. electricity for shearing or milking). Then use biophysical allocation according to energy or protein requirements for animal physiological functions of growth, fiber production, milk production, reproduction, activity and maintenance.
Milk processing to milk products	1. Separate activities 2. Mass of fat + protein	First, separate activities specific to individual products where possible. Then use allocation based on the relative amount of fat + protein in the milk products
Fiber processing to clean fiber and lanolin	1. Separate activities 2. Economic	First, separate the activities specific to individual products where possible. Then use economic allocation based on a minimum of three years of recent average prices.
Meat processing to meat and non-meat products	1. Separate activities 2. Economic	First, separate the activities specific to individual products where possible. Then use economic allocation based a minimum of three years of recent average prices.

* *Note*: Where choice of allocation can have a significant effect on results, it is recommended to use more than one method to illustrate the effects of choice of allocation methodology

Defining a biophysical allocation methodology for handling co-products of milk, meat and fiber from sheep or goats at the farm-gate was most problematical, since this has received little research attention. For sheep or goats where milk is a main co-product, an allocation approach based on relative energy requirements for milk or meat production was considered most appropriate. This method also aligns with that agreed to in international guidelines for milk and meat from dairy cows by the IDF (2010). However, for animals where fiber is an important co-product this allocation approach was considered as less appropriate since fiber production is more commonly limited by protein rather than energy (e.g. CSIRO 2007). Thus, an approach based on use of a protein requirement model was considered as more desirable, but it was recognised that this is relatively untested. Recent studies by Wiedemann et al. (2014) indicated that biophysical allocation based on protein mass of the co-products can give similar results to that using a protein requirement modelling approach and that this may be a simpler methodology to use for allocation between fiber and meat.

An illustration of the effect of method of calculation for allocation between live-weight (for meat) and milk or fiber co-products at the farm gate is given in Table 3, based on use of data from Bett et al. (2007) for a Kenyan smallholder goat milk and meat production system, and from Ledgard et al. (2010) for a NZ hill country sheep production system. This shows relatively large effects of allocation method on the estimated % allocation values. It also shows the importance of applying a sensitivity analysis to illustrate the effects of choice of allocation method on the environmental footprint of co-products from small ruminants.

Table 3. Effect of allocation method on percentage allocation between live-weight (LW for meat) and milk or wool for case study goat or sheep systems

	Goats (Kenya) (Bett et al. 2007)	**Sheep (NZ) (Ledgard et al. 2010)**
Main products	Milk, LW for meat	LW for meat, wool (for carpet-making)
Farm type	Smallholder farm	Extensive-grazing pasture farm
Percent allocation to milk (goats) or wool (sheep):		
Biophysical – energy requirements	70%	16%
Biophysical – protein requirements	n.d.	37%
Biophysical – protein mass	50%	39%
Economic	45%	19%

During the primary processing stage, there can also be multiple co-products depending on the type of main products being processed. As part of the multi-functional output decision tree it was defined that a biophysical allocation approach is appropriate where co-products have similar physical properties and serve similar goals or markets, but that where this does not apply the use of economic allocation is appropriate. Based on these criteria, biophysical allocation is recommended for dealing with different milk products, while economic allocation was identified for handling co-products from fiber and meat processing since the latter produce secondary products for very different end uses. For milk products, fat and protein are the key constituents in the co-products and therefore allocation based on the mass of fat plus protein is recommended. This aligns with recent approaches described for dairy cow milk products (Flysjö 2011; Thoma et al. 2013).

Primary processing of greasy fiber from sheep or goats can result in clean wool, lanolin and residue (vegetable matter and dirt, which usually goes to waste). The latter residue is often a valueless waste, but in some cases it may be further processed to a valuable conditioner or fertilizer, and in such cases it should be treated as a co-product. Economic allocation (based on a recent average of a minimum of three years data to reduce effects of temporal variability) of co-products from primary processing of fiber is recommended. In practice, the recovery of lanolin from greasy wool of sheep amounts to only about 2-7 percent by weight (higher for finer wool and lower for goat fibers) or possibly slightly higher on an economic basis, and therefore most of the resource use and GHG emissions will be allocated to the fiber.

Primary processing of goats and sheep for meat production can result in a wide range of co-products, including hides (for leather), tallow (e.g. for soap, biofuel), pet food, blood (e.g. for pharmaceutical products), fiber and renderable material (e.g. for fertilizer). Also, the proportion and components of the carcass used for meat products for human consumption and for co-products is dependent on culture and economic factors and can differ significantly. In view of the very varied use of these co-products and the protocol relating to the multi-functional output decision tree, economic allocation methodology is appropriate. However, for the various edible meat products, it is recommended that they all be treated the same per-kg (i.e. no separate economic allocation between meat cuts). An example of the differences in weight and relative economic value of different meat cuts and non-meat co-products is given in Table 4 for the average lamb from NZ abattoirs in mid-2009. It shows that there was more than an eight-fold difference in price per kg between the lamb rack and neck cuts of meat and illustrates the potential effect that application of economic allocation between meat cuts could have had. Use of data from Table 4 results in calculated values for the % allocation for meat relative to that for meat plus other non-meat co-products at 88% based on economic allocation and 51% based on mass allocation. This difference reflects the greater economic value of meat than of the non-meat co-products.

Table 4. Variation in the mass and economic value of components of an average New Zealand lamb leaving an abattoir and the effects on allocation calculations (data provided by NZ Meat Industry Association from 2009)

	Average mass of component (kg)	**Component as a % of total mass**	**Price per-kg relative to leg meat**	**Component as % of total economic value**
Meat:				
Neck	0.54	1.5	0.21	0.8
Shoulder	4.6	12.7	0.51	16.1
Rack	1.21	3.4	1.73	14.3
Breast and shank	1.46	4.1	0.47	4.8
Loin	1.43	4.0	1.04	10.2
Legs	4.68	13.0	1.00	32.1
Other meat	2.43	6.7	0.38	6.4
Edible offal	2.0	5.5	0.28	3.9
Co-products:				
Hide/skin	2.21	6.1	0.28	4.3
Wool	1.59	4.4	0.27	3.0
Blood	1.76	4.9	0.01	0.1
Inedible offal	0.65	1.8	0.14	0.6
Rendering/tallow	11.54	32.0	0.04	3.5

4. Conclusions

Key learnings from development of the guidelines included the need to recognize and account for 1) the diversity of small ruminant production and processing systems, 2) the potential for limited data availability, and 3) the importance of several main areas of methodology in determining the final results. The LEAP partnership offered an effective process for stakeholders in the chain to overcome these issues in a concerted manner. The guidelines were structured so that they could be applied to a wide range of production and processing systems using the generic principles and varying levels of specification provided. Additionally, for several processes a hierarchy approach was presented that identified the most appropriate method or data source as well as alternative options that were less detailed or less specific but more achievable for systems with limited data.

Two critical areas of methodology identified were the importance of determining feed requirements by animals and the methods for handling multi-functional processes and allocation. Relatively large sections of the guidelines were dedicated to these areas of methodology, by providing greater specificity on data sources and methods of calculation. In this paper, case study examples were given to show the effects of the methodology choices for co-product handling including allocation options. It was concluded that sensitivity analysis should be carried out and results presented to illustrate the effects of these key methodology choices on the calculated environmental emissions.

An additional learning from development of the draft guidelines for small ruminants concurrently with those for feed and poultry was the importance of harmonization across stages of the supply chain (feed and animal production) and between species. Further adjustments of the Guidelines are expected based on the on-going Public Review and a planned test phase. It is also LEAP's aim to expand the guidelines to the inclusion of other environmental impact categories. This collaborative approach, which is also currently being applied to other species (e.g. large ruminants), has potential to improve consistency in assessing and reporting the environmental performance of livestock and in monitoring improvements.

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