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Greenhouse gas emissions throughout the life cycle of Spanish lamb-meat:
A comparison of three production systems

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Abstract. The livestock sector increasingly competes for scarce resources and has a severe impact on air, water and soil. So far, no study exists that compares the environmental impact of different sheep production systems. We used Life Cycle Assessment (LCA) to evaluate greenhouse gas (GHG) emissions of three contrasting meat-sheep farming systems in Spain, which differ regarding their degree of intensification (reproduction rate, land use and grazing management). The GHG emissions of these systems varied from 19.5 to 28.4 kg CO_2 eq per kg live-animal, or 38.9 to 56.7 kg CO_2 eq per kg lamb-meat. Highest values refer to the pasture-based livestock system, which however also provide several ecosystems services that need to be considered when assessing its environmental impact.

Keywords. Lamb meat – Greenhouse Gases – Life Cycle Assessment.

Evaluation d'émissions de gaz à effet de serre au cours du cycle de vie de trois systèmes espagnols de production ovine

Résumé. *Le secteur élevage est de plus en plus en compétition pour des ressources limitées et a un impact important sur l'air, l'eau et le sol. Jusqu'à maintenant il n'existe pas d'études qui comparent l'impact environnemental des différents systèmes de production ovine. Nous avons utilisé le "Life Cycle Assessment" (LCA, Evaluation du Cycle de Vie) pour évaluer les émissions de gaz à effet de serre de trois systèmes de production de viande ovine en Espagne, qui diffèrent selon leur degré d'intensification (taux de reproduction, utilisation des terres, gestion du pâturage). Les émissions de gaz à effet de serre de ces systèmes varient de 19,5 à 28,4 kg de CO_2 eq par kg d'animal vivant, c'est-à-dire de 38,9 à 56,7 kg de CO_2 par kg de viande d'agneau. Les plus hautes valeurs correspondent au système d'élevage en pâturage, toutefois ce système remplit plusieurs fonctions au sein des écosystèmes qui devront être prises en compte lors de l'évaluation de son impact environnemental*

Mots-clés. *Viande d'agneau – Gaz à effet de serre – Évaluation du cycle de vie.*

Introduction

Since the publication of "Livestock's long Shadow" (Steinfeld *et al*., 2006) public and scientific awareness increased about the major impact of animal production on its environment. The livestock sector increasingly competes for scarce resources and has a severe impact on air, water and soil. Life Cycle Assessment (LCA) is a widely accepted method to evaluate the environmental impact during the entire life cycle of an animal product. Many studies applied life cycle assessment to evaluate the environmental impact of beef, pork, chicken, milk and eggs (De Vries and De Boer, 2010), but only a few studies so far focused on sheep production

(Williams *et al.*, 2006; Edwards-Jones *et al*., 2009; Ledgard *et al.*, 2010). In Mediterranean areas, sheep farming systems (SFS) are generically characterized as extensive, with strong links with natural and semi-natural areas, despite there is a wide range of utilization of inputs, land use, grazing management and productivity rates across regions and farms. They are important because of their multiple economic, environmental and social functions, often in marginal rural areas (De Rancourt *et al*., 2006). In Spain, 87% of sheep are located in Less Favoured Areas (LFA), where small ruminants are often the only possible activity thanks to their capacity to thrive in adverse conditions. However, there has been an important decrement in number of heads: -15% in last 5 years (FAOSTAT, 2010). The aim of this study was to evaluate greenhouse gas emissions along the life cycle of three representative lamb-meat sheep farming systems in Spain.

II – Materials and methods

1. Cases of study

We distinguished three contrasting sheep farming systems according to their degree of intensification regarding reproductive rate, land use and grazing management (Table 1):

(i) *Grazing or pastoral system*: alpine mountains (Central Pyrenees); traditional reproductive management (1 lambing per ewe per year); free grazing of the herd and semi-stall conditions during lactation.

(ii) *Mixed sheep-cereal crop system*: mid-altitude Mediterranean ranges and plateaus (Pre-Pyrenees and Iberian ranges); mid-intensive reproductive management (3 lambings per ewe every 2 years); herd grazing daily with shepherd and indoors at night and during lactation

(iii) *Industrial system or zero grazing*: low altitude semi-arid conditions (Ebro Basin); high-intensive reproductive management (5 lambings per ewe every 3 years); kept indoors all year round.

2. Methodology

Life Cycle Assessment (LCA) is a widely accepted and standardized method to evaluate the environmental impacts during the entire life cycle of a product. The main strengths of LCA lie in its ability to provide a holistic assessment of production processes, in terms of resource use and environmental impacts, as well as identification of hotspots (Cederberg and Mattson, 2000; Thomassen and De Boer, 2005). However, LCA also presents significant challenges, particularly when applied to agriculture: the method places limitations on the comprehensive assessment of complex, interconnected food chain; limited data availability; and multiple-output nature of production (Gerber *et al.*, 2010). This is specially the case for pasture-based SFS, often located on High Value Nature (HVN) farmland, due to the importance of the ecosystem services they provide; e.g. conservation of biodiversity (Henle *et al.*, 2008) and cultural landscapes (Plieninger, 2006).

A. System boundaries and delimitations

We evaluated greenhouse gas emission of three sheep production systems using a life cycle approach. Figure 1 shows schematically the processes included. This assessment follows the attributional approach, which estimates the environmental burden of the existing situation under current production and market conditions (Thomassen, 2008). We quantified emissions of the three most important greenhouse gases emitted from agricultural activities, i.e. carbon dioxide (CO_2), nitrous oxide (N_2O) and methane (CH_4).

Table 1. Farm structure, herd structure and inputs

			Grazing	Mixed	Zero grazing
Farm structure	Total On-Farm Land Use (ha)		110	190	9
	Arable crop land (ha)		-	80	9
	Arable forage land (ha)		-	10	-
	Pastures and meadows (ha)		10	-	-
	Woodland and shrub (ha)		100	100	-
	Communal Off-Farm Land (ha)		750	500	-
	Woodland and shrub (ha)		250	500	-
	Alpine pastures (ha)		600	-	-
Herd details	Breed		Churra Tensina	Rasa Aragonesa	Salz
	Average number of ewes		350	550	1200
	Number of lambs sold per year		296	631	2759
	Average live weight of lamb sold (kg)		22	22	22
	Grazing time (% time spent annually)		90	25	0
Inputs	Energy use	Diesel used (l)	565	3150	9850
		Electricity (kw/h)	-	-	738
	Fertilizers	Nitrogen (kg N/year)	-	920	2700
		Phosphorous (kg P/year)	-	788	2250
		Organic Nitrogen (kg N/year)	360	-	-
	Pesticides	Pesticide (kg/ha)	-	-	1

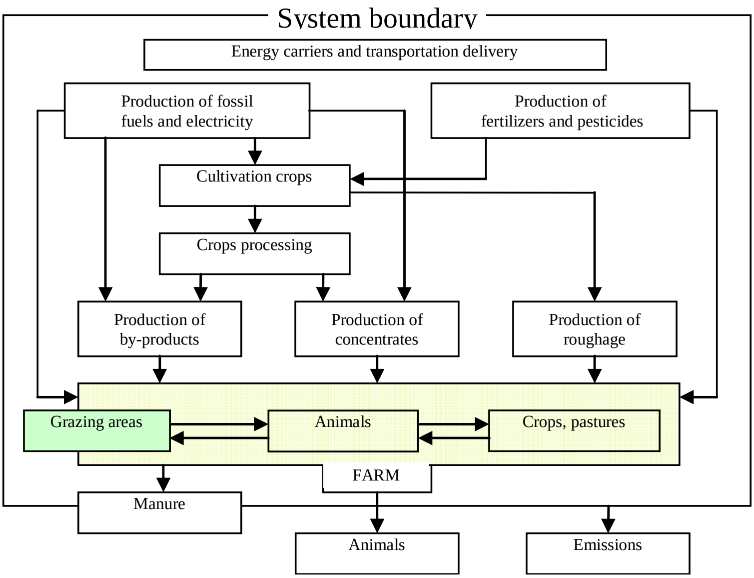

Fig. 1. System boundaries.

B. Functional unit (FU)

LCA relates the environmental impact to a functional unit, which is the main function of a production system expressed in quantitative terms. In the current assessment, the functional unit chosen is one kg of meat lamb. For the Spanish conditions, lambs are slaughtered at an average live weight of 22 kg and with an average dressing percentage of 50%.

C. Inventory analysis

The inventory analysis consists of collection of data concerning resource use and emission of greenhouse gasses of all stages in the life cycle of the three sheep production systems. Farm characteristics of the three systems are presented in Table 1, whereas information regarding the feed ration is in Table 2.

Table 2. Feeding ration and origin† (on/off)

	Feed type	Grazing	Mixed	Zero grazing
Adult	Forage crops	14 (off)	15 (on)	48 (off)
	Grazing	86 (on)	66 (on)	-
	Concentrates	-	13 (off)	-
	Grains	-	6 (on)	-
	Pulps	-	-	21 (off)
	Silages	-	-	28 (on)
	Other by-products	-	-	3 (off)
Lamb	Milk	18	12	8
	Concentrates	74 (off)	80 (off)	84 (off)
	Straw	8 (off)	8 (on)	8 (off)

†Feed produced on-farm (on) or off-farm (off).

In order to compute the emissions from all processes and inputs, a model was performed in MS Excel. The model consists in four main modules to represent simplified sheep-meat farming systems: (i) herd structure and performance; (ii) feed production (assessed both whether on-farm or off-farm production); (iii) animal feeding; and (iv) manure management.

Calculations of emission in the model are based on the IPCC guidelines (IPCC, 2006), particularly the *Volume 4* (Agriculture, Forestry and Other Land Use). Methodological complexity relies on a Tier 2 level for all calculations and values.

The Global Warming Potentials (GWP) values used to convert methane and nitrous oxide into CO_2-eq were 25 and 298, respectively (IPCC, 2007).

The herd model assumes a constant total herd count (no herd dynamics are considered). Among feed crops, only soybean is significantly associated with land use conversion. The study's main data sources include: (i) Statistics from FAO (FAOSTAT, 2010); (ii) Statistics from the National Statistics Year Book (MARM, 2009); (iii) Peer reviewed journals and national publications; (iv) *Federación Española para el Desarrollo de la Nutrición Animal* (FEDNA) and *Sociedad Española para el Estudio de los Pastos* (SEEP), feedstuffs and pasture databases; and (v) Direct interviews to farmers and farm documents.

III – Results and discussion

Table 3 shows preliminary results of greenhouse gas emissions of the three sheep production systems (in CO_2-equivalents per kg lamb) and the contribution CH_4, N_2O and CO_2 (in %) to total emissions. The amount of GHG released for the grazing, mixed and zero-grazing systems was 202, 357 and 1021 ton CO_2 eq per farm per year.

Table 3. GHG emissions (CO_2 eq/kg) for live-weight or lamb-meat and contribution (%) of CH_4, CO_2 and N_2O to total GHGs

	Kg live-weight (CO_2 eq/kg)	Kg lamb-meat (CO_2 eq/kg)	CH_4 (%)	CO_2 (%)	N_2O (%)
Grazing	28.4	56.7	57.0	9.5	33.5
Mixed	24.3	48.5	56.7	20.8	22.6
Zero grazing	19.5	38.9	59.4	29.1	11.5

As expected, global warming potential (GWP) follows an opposite trend to intensification process; the higher the intensification of production the lower the CO_2-eq per kg of product. Many factors can explain that results, such as quality of diet, herd energy requirements, etc., but productivity plays a major role, as the impact is related to final production of meat.

Direct comparisons between studies are difficult due to potentially large differences in the analytical methodologies and the system boundaries adopted (Edward-Jones *et al*., 2009). These authors gave some GHG values for lamb production in the UK, considering a similar system boundary, which fluctuated between 8.1 and 143.5 kg CO_2 eq/kg live weight, due to particularities of the farms analysed. Our values do not vary so much and are located within this range. On the other hand, Willams *et al.*, (2006) attributed 17.5 and 10.1 kg CO_2 eq/kg carcass weight to conventional and organic lamb meat production respectively in another study in UK.

De Vries and De Boer (2010) compared the GWP of diverse livestock products. For meat production, differences in environmental impact between pork, chicken, and beef were explained mainly by 3 factors: differences in feed efficiency, differences in enteric CH_4 emission between monogastric animals and ruminants, and differences in reproduction rates. One kg beef resulted in 14 to 32 kg CO_2-eq for these authors. In our case, low productivity of sheep, large fixed cost in terms of maintenance requirements, and lower quality of the diet could explain the higher values in terms of GHG emission for SFS.

However, the environmental dimensions of sheep production are not restricted to GHG emissions and pollution. In fact, pasture-based livestock farming systems also produce positive externalities, as a strong link with the conservation of biodiversity and cultural landscapes has been demonstrated (Henle *et al.,* 2008; Plienninger, 2006). They also play a central role in the prevention of forest fires in Mediterranean regions (Kramer *et al.*, 2003). These ecosystem services delivered to society often mean higher costs, not only economic (lower productivity of low-input systems), but also in terms of GHG emissions. Therefore, it is a priority to value and integrate these non-market goods into evaluation frameworks for environmental impact assessment and translation into policy design.

Finally, we should also mention that sheep have the ability to valorize "natural and renewable resources" that do not compete with human nutrition and cannot be used for alternative purposes. This advantage becomes a weakness when analysing production systems from the perspective of their GHG emissions, since a low quality diet means higher emissions.

Tradeoffs and synergies between different environmental dimensions of animal production (and between economic, social and environmental sustainability factors) stress the need to develop holistic analytical frameworks to analyze any aspect of sustainability.

IV – Conclusions

Sheep Farming Systems are very diverse and complex and thus, their environmental impacts difficult to evaluate from a holistic perspective. The GHG emissions of Spanish meat-sheep systems varied from 19.5 to 28.4 kg CO_2 eq/kg live weight, or 38.9 to 56.7 kg CO_2-eq/kg lamb meat, in relation to the level of reproductive intensification. However, the strong link between pasture-based livestock production and the provision of several ecosystems services, specially in mountain and other marginal areas, need to be considered and integrated into a standard evaluation framework for environmental impacts of agricultural production, such as LCA.

References

Cederberg C. and Mattson B., 2000. Life cycle assessment of milk production – A comparison of conventional and organic farming. In: *Journal of Cleaner Production,* 8, p. 49-60.

De Rancourt M., Foisb N., Lavín M.P., Tchakérian E. and Vallerand F., 2006. Mediterranean sheep and goats production: An uncertain future. In: *Small Ruminant Research,* 62, p. 167-179.

De Vries, M., De Boer, I.J.M., 2010. Comparing environmental impacts for livestock products: A review of life cycle assessments*.* In: *Livestock Science,* 128(1-3), p. 1-11.

Edwards-Jones G., Plassmann K., Harris I.M., 2009. Carbon footprinting of lamb and beef production systems: insights from an empirical analysis of farms in Wales, UK*.* In: *The Journal of Agricultural Science*, 147, p. 707-719.

FAOSTAT. 2010. Food and Agriculture Organization Statistical Database: http://faostat.fao.org

Gerber P., Vellinga T., Opio C., Henderson B. and Steinfeld H., 2010. *Greenhouse gas emissions from the dairy sector - A Life Cycle Assessment.* Food and Agriculture Organization of the United Nations, Rome, p. 94.

Henle K., Alard D., Clitherow J., Cobb P., Firbank L., Kull T., McCracken D., Moritz R.F.A., Niemelä J., Rebane M., Wascher D., Watt A. and Young J., 2008. Identifying and managing the conflicts between agriculture and biodiversity conservation in Europe – A review. In: *Agriculture, Ecosystems & Environment*,124, p. 60-71.

IPCC, 2006. *2006 IPCC Guidelines for National Greenhouse Gas Inventories. Prepared by the National Greenhouse Gas Inventories Programme.* Japan: IGES.

IPCC, 2007. Technical Summary. In: *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, Cambridge University Press, UK.

Kramer K., Groen T.A., van Wieren S.E., 2003. The interacting effects of ungulates and fire on forest dynamics: An analysis using the model FORSPACE. In: *Forest Ecol. Manag.,* 181, p. 205-222.

Ledgard S.F., Lieffering M., McDevitt J., Boyes M. and Kemp R., 2010. *A Greenhouse Gas Footprint Study for Exported New Zealand Lamb*. AgResearch, New Zealand, p. 24.

MARM, 2009. *Anuario de Estadística 2008*. Ministerio de Medio Ambiente y Medio Rural y Marino. Secretaría General Técnica, Subdirección General de Estadística. Madrid, Spain, p. 1150.

Plieninger T., Höchtl F. and Spek T., 2006. Traditional land-use and nature conservation in European rural landscapes. In: *Environmental science & policy,* 9, p. 317-321.

Steinfeld H., Gerber P., Wassenaar T., Castel V., Rosales M. and Haan C.D., 2006. *Livestock's long shadow: environmental issues and options.* Food and Agriculture Organization of the United Nations, Rome, p. 390.

Thomassen M.A., 2008. Environmental impact of dairy cattle production systems – An integral assessment. PhD thesis, Wageningen University, Wageningen, The Netherlands.

Thomassen M.A. and De Boer I.J.M., 2005. Evaluation of indicators to assess the environmental impact of dairy production systems*.* In: *Agriculture, Ecosystems and Environment*, 111, p. 185- 99.

Williams A.G., Audsley E. and Sandars D.L., 2006. *Determining the environmental burdens and resource use in the production of agricultural and horticultural commodities.* Defra Research Project IS0205. Cranfield University and Defra. Bedford, UK. p. 97.