Integrating social and economic criteria in the carbon footprint analysis in sheep dairy farms

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ABSTRACT

Climate change mitigation has recently become an important goal in our society. It is one the three objectives in the developing of last set of changes in the Common Agriculture Policy for the European Union. LCA methodology is able assess environmental impacts of food production along the food chain. Within LCA studies, carbon foot printing has becoming a popular indicator to communicate results to consumers, producers and all stakeholders involved in food sector. Sheep production is important activity in Southern Europe. Intensification of sheep farms is happening according to the global process of intensification of agriculture and livestock production in general and that involves, the decrease of people who are living in rural areas, the industrialization of the agriculture sector and this is a risk for local and small-scale producers. This paper presents results for emission intensity of two sheep milk systems in Northern Spain using different perspectives: productive (from 2.11 to 5.35 kg CO_2eq/liter of ECM), economic (from 0.84 to 13.4 kg CO_2eq/Net Margin), human resources (from 39,142.34 to 314,799.5 kg CO_2eq/Manpower Unit), and land occupation (from 964.11 to 6,882.43kg CO_2eq/ha). Lower values of emissions have been found for intensive farms per liter of FPCM and highest ones per land occupation, or manpower unit. Although improving efficiency and lowering costs are key factors reduce environmental impacts of food production, a holistic point of view is imperative to consider; and economic and social criteria need to be included in LCA assessments.

Keywords: Carbon footprint, Sheep farming, Multicriteria assessment.

1. Introduction

Climate change is one of the main issues that the livestock sector has been coping with recently (Gill et al, 2010), largely due to the importance of Greenhouse Gas Emissions (GHGs) coming from primary sector, especially from enteric fermentation of ruminants. Overall, 14.5 % of all human-induced emissions are produced by livestock sector (Gerber et al., 2013). Small ruminant's environmental impact is 10% of total methane emissions, and 18.83% of N_2O from manure management. (Gill et al, 2010).

LCA methodology has emerged as a tool useful to monitoring processes and identifies hotspots in different environmental categories, most of them focusing in food production (Flysjö et al, 2011). Global warming is one of them. Carbon footprint (CF) is becoming a popular indicator, considering its facility to understand, and communicate results from consumers and society in general.CF express intensity of kg of CO_2 per unit of product. Nevertheless, CF can generate conflict in other categories inside environmental quality indicators depending how results are reported, where high yield farms could have less emissions per unit produced. For this reason some knowledge is needed regarding the use of CF as an indicator for wider environmental impacts from food products (Röös et al, 2013).There are studies in biography which question if it's a good option increase milk yield per animal to decrease GHGs emission (Zehetmeier et al, 2012).

There is an urgent need to consider social and economic aspects in LCA studies (Flysjö et al, 2012). In addition to global warming impacts, food production also affects the environment considerably in many other ways (Röös et at, 2012) like land and resources demand (Garnett, 2014) .For the other hand, the concept of multifuncionality has become stronger (van der Ploeg & Roep, 2003; Van Huylenbroeck et al, 2007) to attribute more functions to agriculture, a part of providing food and fibres to society. The non-market functions of primary sector have been one of the midpoints of the future of the Common Agricultural Policy (European Commission, 2010) and it one of the justification with the link between the subsides with greener production systems (Matthews, 2013). Nevertheless, socio economic context which LCA results need to be situated (Edwards-Jones, et al, 2009) and different metrics to account GHGs could significantly alter the results and ranking (Reisinger & Ledgard,2013)

The overall aim of this study is to describe GHGs emissions with different functional units in order to extend the system boundary including social and economic factors to the classic environmental assessment. Carbon footprint is a useful conduct for analyzing the potential contribution of a product to climate change, but only efficiency approach (milk production) is taken into account.

This work has the following start point questions,
- How does the functional unit influence in the result of CF?
- Can we use metrics to influence in the interpretation of the results?

2. Methods

2.1. Case study

Sheep production has relevant importance in South Europe (de Rancourt et al, 2006) and in the Basque Country becomes a key sector in production of cheese (Ruíz et al, 2011) in semiextensive systems traditionally with an importance of pasture uplands during summer season. To tackle with the objective of this study, 12 sheep milk farms in the Province of Álava (Basque Country, Northern Spain) have been analyzed. All data was primary taken for SERGAL (advisory farmers association) for year 2011.The study involves this work required, more deeply data than other classical LCA studies, involving environmental, economic and social information of each farm through personal surveys and several visits every month.

Table 1. Main technical characteristics of farms analyzed in this study.

	Minimum value	**Maximum value**
Land occupation (ha)	29.1	229.1
Average annual temperature (ºC)	10.2	12.1
Workers (number)	1	5
Milk ewes (average population)	108	835.1
Annual production (liters of milk)	20,946	233,267
Liters/ewe year	109.1	399.4
Lambs (annual sales)	134	424
Lamb sold/ewe	0.4	1.16
% time grazing	0%	52.7%
Concentrate (kg/year)	29,185	388,495
Fodder (kg/year)	5,880	237,560
Oil(liters/year)	1,269.2	18,478
Electricity (kwH/year)	2,350	37,431.1
Mineral fertilizer (kg/year)	0	61,712.4
Prize milk (euros/liters milked milk)	0.77	2.4
Prize lambs (euros/kg lamb)	3.06	5.08

The main differences visible in farms are the high production of intensive farms (average yield per sheep 325 liters/year) with more traditional farms (average yield per sheep 110 liters/year); housing of intensive management flock (0% grazing per year) comparing with traditional flocks (approx. 48% grazing in natural grasslands); and price of sale of milk from 0.77 euros/liter at farm gate to those farmers who sell milk to industry to 2.4 euros/liter of milk to those who make cheese in their own farms and sell directly to consumers in local markers.

CF is been calculated following guidelines of PAS2050 (BSI, 2008) and IPCC criteria for livestock and soil emissions (IPCC, 2006).

2.2. System boundary

In order to integrate social and economic dimensions into LCA studies, environmental boundary has been integrated with social and economic boundaries. The system used in this study (Figure 1) coverts from cradle to farm gate. It includes emissions arising from manufacture and distribution of farm inputs ,the use of energy on the farm (fuels and electricity), the GHG emissions from livestock and their excreta, and emissions from soils related to fertilizer use and manure management. Nevertheless, environmental boundary does not take into account economic and social aspects as prices of inputs and sale prices, land occupation of the flock, as well as manpower units and relation of the farms with the environment. Thereby not only environmental resources are included in the assessment.

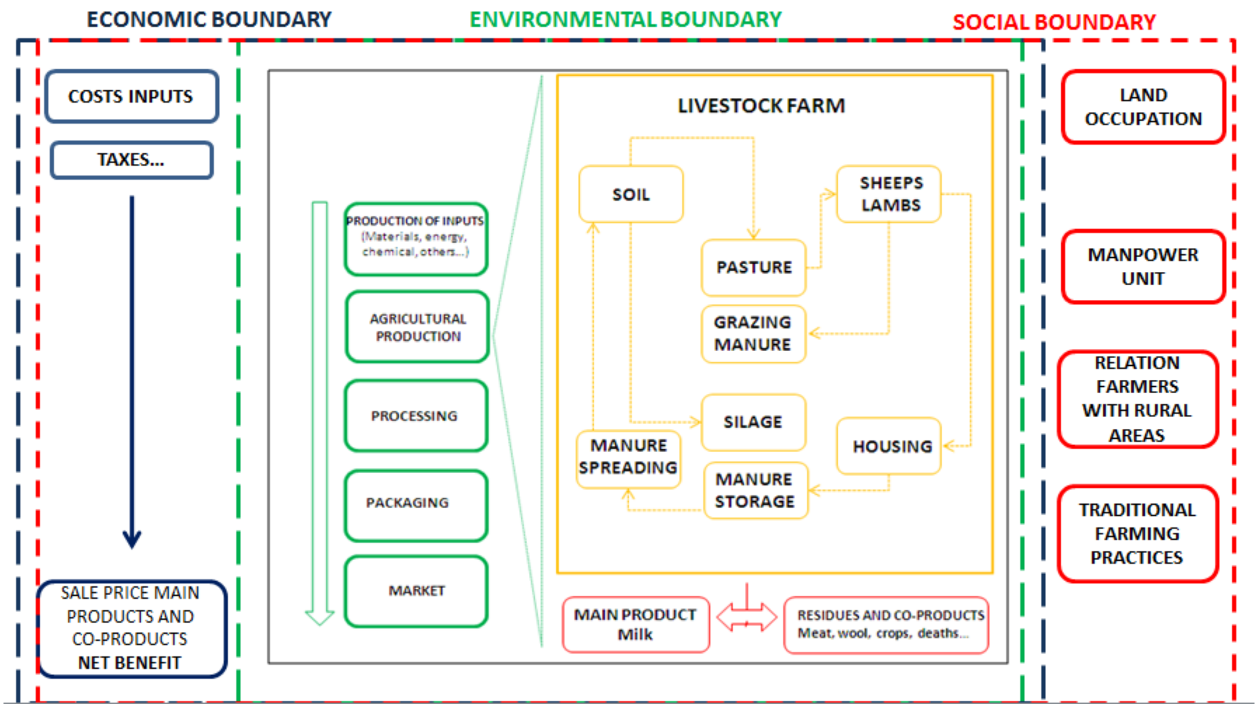

Figure 1. System boundary.

Emissions on farms and off farms (from production and manufactured of inputs) have been included in the breakdown GHG fluxes considered. According with system boundary, Table 2 shows these sources of emissions as well as the gases involved in each study and the source of the emission factor used. All the emissions are given in kg CO_2 equivalent, in accordance to the global warming potentials (GWP100) available from IPCC (2007).

Table 2. Source of emissions and models used in the study.

Sources of emissions	Gas	Source	OFF FARM/ON FARM Emissions
Enteric fermentation	CH_4	Torres et al (2004)	ON FARM
Manure management	CH_4	(IPCC, 2006)/MAGRAMA (2011)	ON FARM
Manure management	N_2O	IPCC 2006	ON FARM
- **Direct N_2O emissions**		Equation 10.25	
- **Indirect N_2O emissions**			
- **Volatilization**		Equation 10.26, 10.27	
- **Leaching**		Equation 10.28, 10.29	
Emissions from managed soils	N_2O	IPCC 2006	ON FARM
- **Direct N_2O emissions**		IPCC 2006, Equation 11.1, 11.2, 11.3, 11.4, 11.5, 11.6, 11.7, 11.8	
		IPCC 2006, Equation 11.9, 11.10, 11.11	
- **Indirect N_2O emissions**			
Emissions from liming	CO_2	IPCC 2006 Equation 11.11	ON FARM
Emissions from urea fertilization	CO_2	IPCC 2006 Equation 11.12	ON FARM
Energy use of farm (fuel and electricity)	CO_2	GES´TIM & IBERDROLA	OFF FARM/ON FARM (combustion)
INPUTS (feed, fertilizers, pesticides...)	CO_2	GES´TIM	OFF FARM

2.3. Functional unit and allocation

The functional unit (FU) is the unit which all GHGs emissions are reported relative to it. The FU is a measure of the function of the studied system and it provides a reference to which the inputs and outputs can be related, for that reason is a key element in the later work of reading the results. Traditionally, LCA studies on milk production use “1 kg of milk at farm gate” as functional unit. Table 3 shows the four functional units proposed in this study to cover economic, social and environmental boundary for the global warming potential of sheep milk production.

Table 3. Functional units proposed in the study.

Functional unit	Unit	Aspect to study
Energy Correct Milk	Kg ECM	Productive. Efficiency
Hectares	ha	Land Occupation
Manpower Unit	Number worker	Human resources
Net Margin	Euros	Economic/profitably

- Energy Corrected Milk (ECM). Milk yield from dairy sheep was corrected according to Bocquier et al, (1993) at 1200 kcal/liter of sheep milk.

$$ECM = 0{,}071 * fat\ (\%) + 0{,}043 * protein\ (\%) + 0{,}2224 \qquad \text{Eq. 1}$$

- Hectares. Number of hectares that has been used by the sheep flock for feeding purposed during a year. This functional unit is proposed to focus the importance of land occupation by grazing for livestock, especially in less favorable areas, as uplands.

- Manpower Unit. Number of employee people on the farms. This functional unit copes to human resources necessary for milk production.

- Net Margin (NM). Difference between the sold price of outputs and the cost of all the inputs necessary for production including taxes. Profit of the farmer.

As shown in Figure 1, sheep production has edible and no edible products as outputs. Economic allocation was used to allocate GHGs emissions between milk, lamb and wool production. The reason of using economic allocation in the study is that in this case study, the main purpose of these farms, it is the milk sheep production, and lambs and wool are only co-products relative to the main production.

3. Results

Total emissions per ha, per Net Margin, per kg ECM produced and per Manpower unit are presented in Table 4 in maximum, average and minimum values.

Table 4. CF according with functional units (Minimum, average and maximum values).

Carbon footprint	Minimun values	Average values	Maximun values
Kg CO2-Equivalente / ha	964.11	3,190.75	6,882.43
kg CO2-Equivalente / NM	0.84	5.13	13.40
Kg CO2-Equivalente / Manpower Unit	39,142.34	131,309.69	314,799.50
kg CO2-eq/kg ECM	2.11	3.35	5.35

Using kg ECM corrected milk as FU, farms with high production (323 liters/ sheep year), will have lower CF. Normally these farms, are farms which lower land occupations, and with higher kg CO_2 eq/ha.

Figures 1, 2, 3 and 4 presents the correlation between emissions per functional unit and that functional unit, to highlight that depends in the functional unit chosen the way of read the results can be complete different.

Correlations between CF and functional units have been studied. There are no high correlations in any of the functional unit chosen in this study. Moderate negative correlation R^2 =-0.65 per ha (surface) and R^2 = -0.62 when Net Margin is the functional unit. On the other hand, positive correlation R^2 =0.41 for manpower unit, and high-moderate positive correlation, R^2=0.89 when liter per ewe is functional unit. Bigger differences can be seen between kg CO_2 per kg ECM and kg CO_2 per ha. If results are only given per kg ECM produced intensive production have lower emissions per functional unit, but these farms have higher emissions per land occupation.

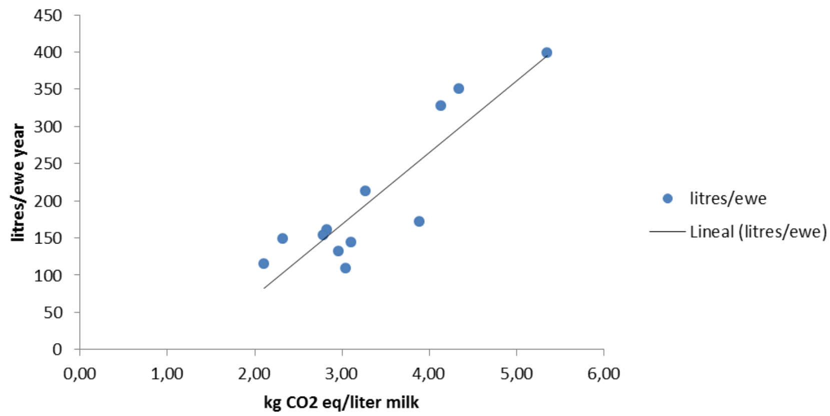

Figure 1. Relation between CF and milk annual production per sheep**.**

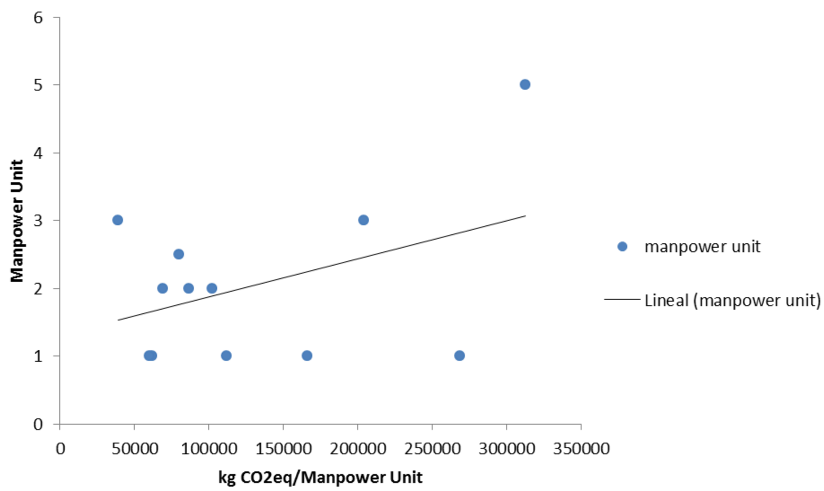

Figure 2. Relation between CF and Manpower unit.

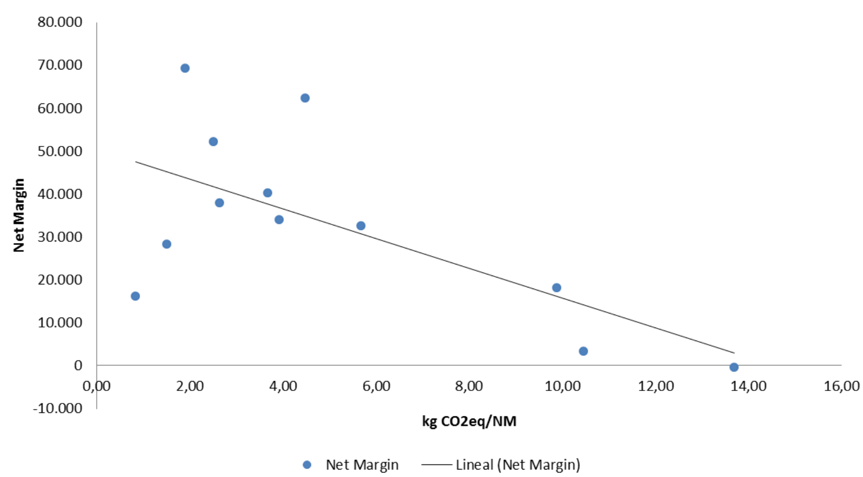

Figure 3. Relation between CF and profitability.

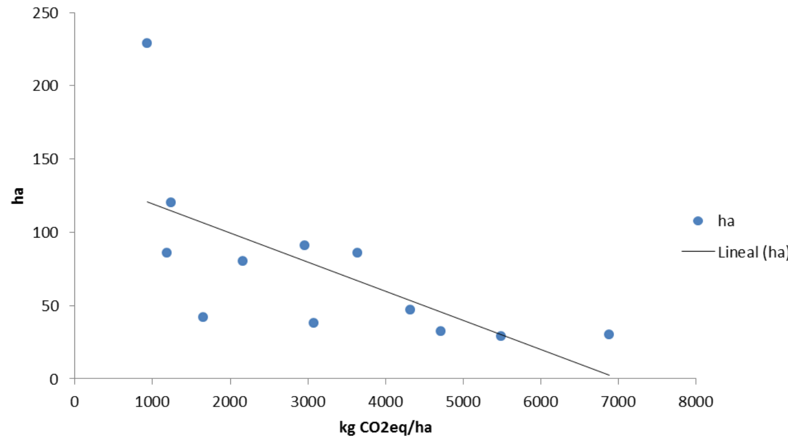

Figure 4. Relation between CF and land occupation.

4. Discussion

CF gives a number that means the contribution of one product to climate change. Table 4 shows results to the farms studied, emissions of 1 kg ECM are from 2.11 to 5.35 kg CO_2 eq/kg ECM. These results are similar to other studies, as Opio et al. (2013), Weiss and Leip (2012). If we only take into account this indicator as criteria of environmental assessment, we would choose the farm with lower CF as the most climate change friendly. In this example, the farm with lower CF corresponds to a very intensive management farm; totally different to the traditional sheep milk production in The Basque Country. Meanwhile, the one with higher CF corresponded with a traditional farm with grazing as important feed resource for the flock, typical from uplands in this territory. It is necessary not only think in productive functional unit (not only efficiency could be the criteria) and CF message could be misunderstood. Table 5 displays how farms can have the maximum and minimum value depends in which functional unit we take into account. For example, farm number 11 has one of the maximum values of CF per kilogram of ECM, but in the other hand, has one of the lowest values of emissions per hectare. This is an example of how traditional farms, less productive than the intensive could have higher intensity of emissions if we only focus in productive functional units.

Table 5. Benchmarking of the 12 farm studied depending in the different functional units.

	kg CO_2-eq/kg ECM	**kg CO_2-Eq/ NM**	**Kg CO_2-Eq / Ha**	**kg CO_2-eq/Manpower Unit**
Farm with maximum value	Farm 12	Farm 7	Farm 1	Farm 1
	Farm 11	Farm 9	Farm 10	Farm 9
	Farm 6	Farm 1	Farm 4	Farm 11
	Farm 7	Farm 2	Farm 12	Farm 7
	Farm 5	Farm 3	Farm 3	Farm 12
	Farm 4	Farm 6	Farm 11	Farm 8
	Farm 8	Farm 8	Farm 2	Farm 6
	Farm 10	Farm 12	Farm 6	Farm 4
	Farm 9	Farm 10	Farm 9	Farm 10
	Farm 1	Farm 4	Farm 5	Farm 3
	Farm 2	Farm 5	Farm 7	Farm 2
Farm with minimum value	Farm 3	Farm 11	Farm 8	Farm 5

Fig 5 presents kg CO_2/kg ECM and kg CO_2/ha for the farms studied. Dots represent kg CO_2/kg ECM and bars represent kg CO_2/ha. In general the one with are higher with one criteria are the lowest values for the other.

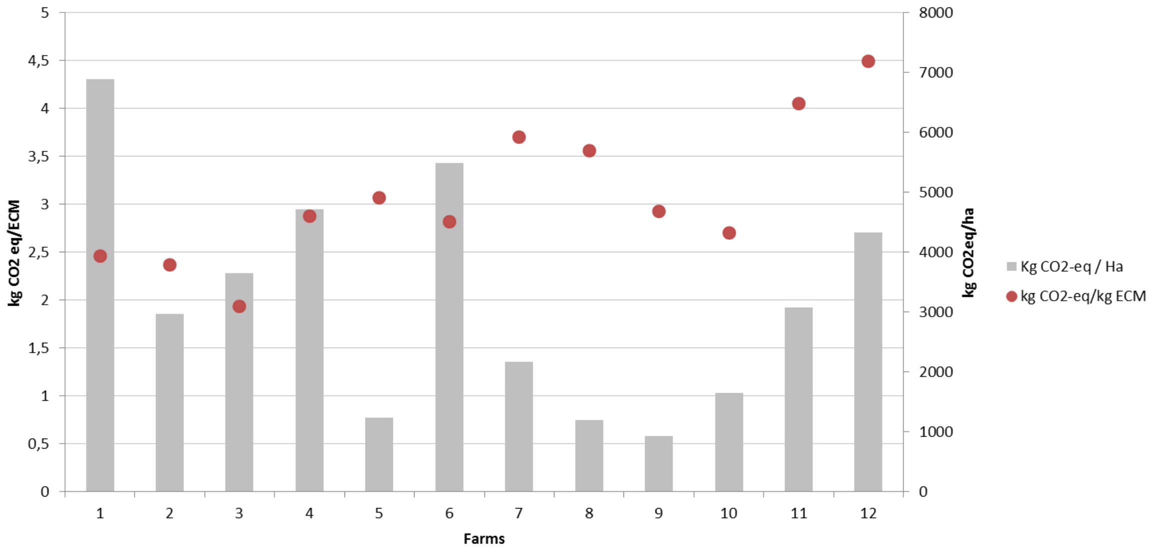

Fig 5. kg CO_2/kg ECM and kgCO_2/ha in the 12 farms studied.

5. Conclusion

Although improving efficiency, lowering cost are key factors on improve environmental impacts of food production, a holistic point of view is imperative to consider; and economic and social indicators are needed to include in LCA assessment.

CF is a useful indicator to monitor emissions by individual farms. Nevertheless, when results between farms are compared, these numbers could be misunderstood, particularly when high differences of efficiency occur within them. This work presents how using different number to express emissions, using different FU could arrive to different results, depending on the socio-economic context.

LCA studies need to take into account other aspects beyond yield to enlarge system boundary and strengthen role of alternative production systems (organic, traditional productions) and several functions given to primary sector nowadays.

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