Environmental analysis of the production of alfalfa

A. Gallego, A. Hospido, M.T. Moreira and G. Feijoo
Department of Chemical Engineering, Institute of Technology, University of Santiago de Compostela. Santiago de Compostela. Spain.
Corresponding author: agallego@usc.es

Keywords: life cycle assessment, alfalfa, dairy cows

ABSTRACT

Spain occupies the 6th position in annual milk production in the European Union [1]. Within Spain, Galician dairy cattle plays a fundamental role with a contribution of 30.92% [2]. According to an study of milk production in this region [3], cow feed (maize, silage, alfalfa and fodder) is one of the main contributors to nearly all impact categories. In this sense, a revision of the provision of those elements is being carried out.

This paper presents in particular the work that is under development on the environmental analysis of alfalfa using Life Cycle Assessment (LCA)

1. Introduction

In 2003, Galicia (NW Spain) produced 2,221,551 litres of milk, representing 30,92% of the total production of Spain [2], which occupies the 6th position in annual milk production in the European Union [1]. An LCA of milk production in Galicia was performed, concluding that cattle feed was one of the major sources of impact [3]. Inventory data used did not proceed from Galicia, as there was no data available for this region. A revision of those data was considered as the starting point of this study.
As can be observed in table 1, Galicia is not a great producer of alfalfa, as the typical soil characteristics difficult this crop production. In fact, Galician farmers use to buy alfalfa from producers out of Galician borders. Taking this into account, the LCA has been based in data from Castilla-León, due to its proximity to Galicia, and from Ebro Valley (Navarra, Aragón and Cataluña), which are the largest production regions.

Table 1. Humid production of alfalfa in Spain [4]

Region	Humid Production (t)
Andalucía	430,125
Aragón	4,867,982
Asturias	8,600
Baleares	62,280
Canarias	2,828
Cantabria	9,652
Castilla La Mancha	1,470,906
Castilla- León	1,385,889
Cataluña	2,050,086
Extremadura	168,900
Galicia	3,975
Madrid	76,318
Murcia	44,182
Navarra	452,881
País Vasco	28,384
Rioja	87,014
Valencia	121,782
España	11,271,782

2. Goal and scope definition

The main objective of the study is to update the inventory data of alfalfa production in order to quantify the environmental effects of all the activities related to this foodstuff supply. At present the inventory is still under development and no final results can be presented.

3. Functional Unit

The functional unit selected is 1 ha of alfalfa/cycle. On average, one cycle equals 4.5 years [5]. Therefore, all the activities that only take place once per cycle will have a factor of 1, while the activities that occur annually by a factor of 4.5.

4. Description of the system

The system under study was divided in three subsystems:

- Soil management and sowing.
- Maintenance and harvesting.
- Dehydrate and transport

4.1. Soil management and sowing. Description and inventory.

Alfalfa cultivation starts with a deep plowing with a chisel-subsolier in order to turn over and drainage the soil. Then, a disc harrow roller levels out the soil and prevent it from getting flooded. At the same time fertilizers and herbicides are applied to get the soil ready for sowing. Before seeding, operations of harrowing and rolling will leave the soil in perfect conditions. In the area of study, seeding is often done with a cereal seeder [5]. The characteristics of the area require the addition of water, therefore, two irrigations (1,000 m^3/ha each one) are considered on average [6]

In table 1, data from tractors in different tasks are included, being the data from agricultural machineries (chisel-subsolier….) under study. Table 2 includes inventory data collected so far.

Table 1. Data from tractor in different tasks

	Hp Tractor	*Diesel (L/FU)*	*Speed (h/ha)*	*Oil (L/FU)*	*References*
Tractor (chisel-subsolier)	100	20	1	0.25	[7, 8]
Tractor (disc harrow)	72	14.4	1	0.25	[7, 8]
Tractor (roller)	100	5	0.25	0.06	[7, 8]
Tractor (field sprayer herbicide 600 l)	60	12	1	0.25	[7, 8]
Tractor (fertilizer spreader centrifugal)	60	3.6	0.3	0.25	[7, 8]
Tractor (rotary harrow)	100	7	0.35	0.25	[7, 8]
Tractor (cereal seeder)	100	14	0.7	0.25	[7, 8]

Table 2. Inventory data for the subsystem soil management and sowing

Known inputs from the technosphere		
N, fertilizer	29.7 kg/FU	[5]
P_2O_5,fertilizer	100 kg/FU	[9]
Benfluralin, herbicides	0.4 kg/FU	[9]
Irrigation, electric consumption	9,748 KWh/FU	[7]
Water, irrigation[a]	2,000 m^3/FU	[5]
Seed	35 kg/FU	[5]
Emissions to air		
$N-NH_3$	0.89 kg/FU	[10]
$N-N_2O$	0.36 kg/FU	[10]
Emissions to water		
$P-PO_4^{3-}$	1 kg/FU	[11]
$N-NO_3^-$	15 kg/FU	[11]

[a] 85% tap water and 15% water from well [6]

4.2. Maintenance and harvesting.

Fertilizers (inorganic and cattle, pig and sheep slurry), insecticide and herbicides are annually added with centrifugal fertilizer drills and fields sprayer during the growing of the crop. The commonest plagues in the area are black bean aphid (*Aphis fabae),* green peach aphid *(Myzus persicae)* and the *Colaspidema atrum*. Accordingly, the typical insecticides used are cypermethrin and malathion and the typical herbicides, asulam and hexazinone. Eight more irrigations are required each year [6]. The harvester makes on average 7 cuts/year [7]. After that, the harvested alfalfa is windrowed and gathered in by a self-loading trailer.

Like in the first subsystem, data from tractors in different tasks are included (Table 3). Table 4 includes inventory data collected so far.

Table 3. Data from tractor in different tasks

	Hp Tractor	*Diesel (L/FU)*	*Speed (h/ha)*	*Oil (L/FU)*	*References*
Tractor (harvester, 7 cuts/year)	72	129.6	2	2.25	[7, 8]
Tractor (windrower, 7 times/year)	72	64.8	1	1.125	[7, 8]
Tractor (field sprayer insecticide 600 l)	60	54	1	1.125	[7, 8]
Tractor (field sprayer herbicide 600 l)	60	54	1	1.125	[7, 8]
Tractor (fertilizer spreader)	60	16.2	0.3	0.3375	[7, 8]
Tractor (vacuum tanker 5000 l)	100	126	1.4	1.575	[7, 8, 12]
Tractor (self-loading-trailer)	100	13.5	0.3	0.75	[7, 8]

Table 4. Inventory data for the subsystem maintenance and harvesting

Known inputs from the technosphere		
N ,fertilizer	158 kg/FU	[5]
P_2O_5,fertilizer	655 kg/FU	[5]
K_2O,fertilizer	529 kg/FU	[5]
Cattle, slurry	5,5278 kg/FU	[5]
Pig, slurry	26,496 kg/FU	[5]
Sheep, slurry	43,740 kg/FU	[5]
Asulam, herbicides	1.26 kg/FU	[5]
Hexazinone, herbicides	0.69 kg/FU	[5]
Cypermethrin, insecticide	2.7 kg/FU	[5]
Malathion, insecticide	0.108 kg/FU	[5]
Nitrogen fertilizer, avoided	277 kg/FU	[13]
Irrigation, electric consumption	544 KWh/FU	[7]
Water irrigation[a]	45,000 m^3/FU	[5, 6]
Emissions to air		
N-NH_3	52.21 kg/FU	[10]
N-N_2O	4.57 kg/FU	[10]
Emissions to water		
P-PO_4^{3-}	4.5 kg/FU	[11]
N-NO_3^-	67.5 kg/FU	[11]

[a] 85% tap water and 15% water from well [6]

4.3. Dehydration and transport.

After harvesting, humid alfalfa is dehydrated and then transported to dairies farms. Data for dehydration were collected from a dehydration plant (Hedesga). Fresh alfalfa, after a weak of natural drying, enter the plant with

35% humidity and is dehydrated by the heat from an industrial boiler. The alfalfa leaves the plant with a humidity of 12%.

Transportation, estimating that one half of the production comes from Castilla-León and the rest from Ebro Valley, is 27276 tkm.

Table 5. Inventory data for subsystem dehydration and transport

Known inputs from the technosphere	
Alfalfa, 35 % humid	67275 kg/FU
Baler	66,3 L gas oil/FU
Truck, 40 ton	17816 tkm/FU
Thermal energy	2,31*10^7 Kcal/FU
Known outputs to technosphere	
Alfalfa, 12 % humid	44208 kg/FU

5. Perspectives

Taking into account the data compiled, it will completed and improved with information from interviews to farmers. All these values will be analyzed with the CML 2 baseline 2000 methodology developed by Leiden University is selected for the LCIA stage [14].

6. Acknowledgements

This work was financed by the Regional Government of Galicia, Xunta de Galicia (Project Reference: PGIDIT04TAL269003PR).

7. References

[1] Eurostat, 2006, Food: From farm to fork statistics. Luxemburg. Available at: http://epp.eurostat.ec.europa.eu/cache/ITY_OFFPUB/KS-51-05-473/EN/KS-51-05-473-EN.PDF. 2006.

[2]. MAPA, 2006, Anuario de Estadística Agroalimentaria 2004. Madrid. Available at: http://www.mapya.es/es/estadistica/pags/anuario/Anu_03/indice.asp.

[3] Hospido, A., 2005, Life cycle assessment as a tool for analysing the environmental performance of key food sectors in Galicia (Spain): milk and canned tuna, PhD Thesis, Department of Chemical Engineering. 2005, University of Santiago de Compostela.

[4] CTA, Centro de Técnicas Agrarias, 2005, El cultivo de la alfalfa en Aragón. Recientes ensayos sobre variedades. Informaciones Técnicas, 157-163.

[5] Alvaro, J. and Lloveras, J., 2003, Metodología de la producción de alfalfa en España. Asociación Interprofesional de Forrajes Españoles. Lleida.

[6] Arnal, P., 2001, Estudio económico del cultivo de la alfalfa. Asociación empresarial agropecuaria Asaja Huesca. Available at: http://www.infonegocio.com/asajahuesca/publicaciones/alfalfa.pdf.

[7] Guerrero, A., 1999, Cultivos herbáceos extensivos. Mundi-Prensa. Madrid.

[8] Mingot, M., 1974, El tractor agricola: utilización y costos de trabajo. Editorial Agrícola Española. Madrid.

[9] Llorca, M., 1999, La Alfalfa deshidratada: cultivo, transformación y consumo. Asociación Interprofesional de Forrajes Españoles. Edicions de la Universitat de Lleida.

[10] Brentrup, F., Küsters, J. Lammel, J. and Kuhlmann, H., 2000, Methods to estimate on-field nitrogen emissions from crop production as an Input to LCA studies in the Agricultural Sector. International Journal of Life Cycle Assessment 5(6): p. 349-357.

[11] Audsley, E., Alber, S. Clift, R. Cowell, S., Crettaz, P., Gaillard, G., Hausheer, J., Jolliett, O., Kleijn, R., Mortersen, B., Pearce, D., Roger, E., Teulon, H., Weidema, B and van Zeijts, H., 1997, Harmonisation of environmental life cycle assement for agriculture. Final Report. Available at: htpp://www.silsoe.cranfield.ac.uk/iwe/expertise/or.htm.

[12] Nemecek, T., et al., 2004, Report No. 15: Life Cycle Inventories of Agricultural Production Systems.

Ecoinvent Database. The Swiss Centre for Life Cycle Inventories. Zurich (Switzerland).
[13] Gallego, A., et al., 2007, Eutrophication caused by aerial NH3 in Galicia (NW Spain). Atmosfera (in preparation).
[14] Guinée, J.B., Gorreé, M. Heijungs, R. Huppes, G. Kleijn, R. de Koning, A. van Oers, L. Weneger, A. Suh, S. Udo de Haes, H.A. de Bruijn, H. van Duin, R and Huijbregts, M., 2001, Life Cycle Assessment: An operational guide to the ISO standards. 2001, Ministry of Housing, Spacial Planning and Environment. The Netherlands.