Journal of Cleaner Production 112 (2016) 91–102

Contents lists available at ScienceDirect

Journal of Cleaner Production

journal homepage: www.elsevier.com/locate/jclepro

Environmental impacts of different dairy farming systems in the Po Valley

F. Battini [a, *], A. Agostini [b, c], V. Tabaglio [a], S. Amaducci [a]

[a] Institute of Agronomy, Genetics and Field Crops, Università Cattolica del Sacro Cuore, Via Emilia Parmense 84, 29122 Piacenza, Italy
[b] STU Unit, JRC-IET – European Commission, Westerduinweg 3, 1755LE Petten, The Netherlands
[c] ENEA–Italian National Agency for New Technologies, Energy and the Environment, Via Anguillarese 301, Rome, Italy

ARTICLE INFO

Article history:
Received 6 March 2015
Received in revised form
16 September 2015
Accepted 16 September 2015
Available online 28 September 2015

Keywords:
Life cycle assessment
Dairy farm
Land use change
Greenhouse gas
Environmental impacts

ABSTRACT

An environmental Life Cycle Assessment (LCA) was performed to compare four typical milk production systems of the Po Valley: drinking milk (A); Parmigiano-Reggiano more intensive (B); Parmigiano-Reggiano less intensive (C) and Grana Padano (D). The input and output data were collected directly from the farmers by way of questionnaires.

The results indicated that the total GHG emissions from the analysed farms, with biological allocation, were: 1.47, 1.35, 1.49 and 1.50 kg CO_2 eq. kg^{-1} FPCM (Fat Protein Corrected Milk) for farm A, B, C and D respectively. Excluding Land Use Change (LUC) emissions and Soil Organic Carbon (SOC) sequestration, total GHG emissions were reduced to 1.02, 1.11, 1.26 and 1.20 kg CO_2 eq. kg^{-1} FPCM for farm A, B, C and D respectively. These reductions were mostly due to the GHG emissions associated to the LUC from imported soybean meal, while the contribution of SOC sequestration to the total GHG emissions was found to be negligible.

When LUC emissions from imported soybean meal were not included in the analysis, lower GHG emissions were associated to higher milk yield, feed self-sufficiency and feed efficiency. However, when LUC emissions were included in the analysis, the highest level of these parameters did not always lead to a reduction of the total GHG emissions because the higher use of maize silage was associated with an increase in the use of imported soymeal.

The results of this LCA also indicated that marine eutrophication, freshwater eutrophication, non-renewable energy use, land occupation and total biodiversity loss decreased as the level of intensification of the production system increased. Conversely, local biodiversity loss, instead, increased if the milk yield per cow increased. We can conclude that, in the specific context analysed, the increase in productivity may lead to a trade-off between global impacts (such as GHG emissions) and local impacts (e.g. local biodiversity and eutrophication).

1. Introduction

Greenhouse gas (GHG) emissions from agriculture, including crop and livestock production, forestry and associated land use changes, are responsible for up to 30% of the anthropogenic GHG emissions (Tubiello et al., 2013). The total GHG emissions from the livestock sector were estimated to be 7.1 Gt CO_2 eq. yr^{-1} (14.5% of all anthropogenic emissions), with cattle being the main contributor to the sector emissions, generating about 4.6 Gt CO_2 eq. (65)% of the livestock sector emissions (Gerber et al., 2013).

Concern over the contribution of livestock and the dairy sector to climate change, has fuelled the interest of the scientific community and subsequently a number of Life Cycle Assessment (LCA) studies were performed to improve the understanding of the GHG emissions from the dairy sector.

Reviewing data from 38 countries worldwide, Hagemann et al. (2011) reported that the GHG emissions of bovine milk production systems ranged between 0.8 and 3.07 kg CO_2 eq. kg^{-1} milk. At European level, Fantin et al. (2012) reported GHG emissions ranging between 0.8 and 1.5 kg CO_2 eq. kg^{-1} milk. This large variability depends not only on environmental conditions and farming

* Corresponding author.
E-mail addresses: battifer@libero.it, ferdinando.battini@unicatt.it (F. Battini).

http://dx.doi.org/10.1016/j.jclepro.2015.09.062
0959-6526/

systems, but also on the assumptions, models and system boundaries adopted in each study.

A review of LCAs within the EU27 (Bellarby et al., 2013) showed that most studies set the system boundary at the farm gate and only few considered Land Use Change (LUC). Flysjö et al. (2012) analysed the carbon footprint of milk including LUC and showed that different LUC accounting methods lead to significantly different results. The authors concluded that it is important to report LUC factors separately and clearly explain the underlying assumptions.

Using a LCA approach, Guerci et al. (2013b) analysed the environmental impact of 12 dairy farms in Denmark, Germany and Italy representing different production methods (organic versus conventional), summer feeding systems (confinement versus pasture) and annual production levels. The study found that the proportion of grassland in the farming system and the feed efficiency in the herd, were the parameters that influence the most the environmental impact. This study introduced for the first time the impact of milk production on biodiversity in the Po Valley.

Many studies compared conventional and organic dairy systems (Cederberg and Mattson, 2000; Haas et al., 2001; de Boer, 2003; Cederberg and Flysjo, 2004; Thomassen et al., 2008; Sonesson et al., 2009; Kristensen et al., 2011; Flysjo et al., 2012), or seasonal pasture-based and confinement systems (Arsenault et al., 2009; O'Brien et al., 2012; Belflower et al., 2012). In the Po Valley the situation is rather complex due to the coexistence of different systems for the production of PDO (Protected Designation of Origin) cheeses such as Parmigiano-Reggiano and Grana Padano.

The Po Valley is the largest milk production region in Italy, characterized by farm efficiency and economic parameters that exceed the national average (Pieri, 2013). The produced milk has several markets; the most important are Parmigiano-Reggiano PDO, Grana Padano PDO and drinking milk.

Parmigiano-Reggiano is produced in five provinces on the south bank of the river Po; Parma, Reggio Emilia, Modena, part of Bologna and Mantua. Grana Padano is produced in a wider area mainly on the north bank of the river, while drinking milk is produced throughout the whole Po Valley, especially in Lombardy.

The Grana Padano and Parmigiano-Reggiano are the most important PDO Italian cheeses in terms of amount of production and export. IES, 2012, the production of Grana Padano was 170834 t, while it was 121822 t for Parmigiano-Reggiano (ISMEA, 2013).

Parmigiano-Reggiano is produced following strict rules defined by the producer association (Consorzio del Formaggio Parmigiano Reggiano, 2015) in particular the use of silage feed is prohibited. Additional feeding regulations result in a relatively low dairy cows stocking rate: at least 50% of forage dry matter has to be supplied by forage produced on the land of the farm where the cows are kept; at least 75% of forage dry matter has to be supplied by forage grown in the area of production.

In the case of Grana Padano, only the second regulation applies; furthermore, the use of maize and other ensiled forages is allowed according to the Specification Rules for the Production of Grana Padano cheese (Consorzio per la tutela del Formaggio Grana Padano, 2015). Therefore, in the area of production of Grana Padano, the base forage ration consists of silage (mainly maize), while in the area of production of Parmigiano-Reggiano it is mainly based on lucerne hay. The main objectives of this work were the analysis of the contribution of farming processes to the environmental impacts of milk production in the Po Valley, and the identification of the trade-offs among environmental impacts due to the adoption of different farming practices. This work is aimed at filling the knowledge gap due to the lack of comparability among LCA assessments performed with inconsistent methodological approaches or geographical scopes. TTo our knowledge this study is the first, to compare different dairy farming system in the same geographic area, using a full LCA approach (i.e. analysing several environmental impacts) and including aspects often overlooked, such as LUC, SOC sequestration and biodiversity.

2. Materials and methods

2.1. Goal and scope definition

In this study the environmental impact of milk production of four farms in the Po Valley is assessed. The impact categories analysed are: Climate Change, Acidification, Eutrophication, Non-renewable energy use, Land occupation and Biodiversity Loss. With the aim to identify the farming processes and characteristics that have the highest contribution to the environmental impact of milk production, a Life Cycle Assessment (LCA) was carried out onfour dairy farms. LCA is a structured, comprehensive and internationally standardised method that aims at quantifying all relevant emissions and resources consumed and the related environmental and health impacts and resource depletion issues that are associated with any product or service. LCA is widely acknowledged as the most suitable tool to assess the environmental impacts of a product or a process (ISO, 2006a; IES, 2010).

The LCA is performed according to the ISO 14040 and 14044 standards (ISO, 2006a; 2006b), using the software GaBi 6 from PE International (PE International, 2013). The background data used are from the Ecoinvent database (Ecoinvent, 2010).

2.1.1. Functional unit, system boundary and allocation

The functional unit is one kilogramme of Fat and Protein Corrected Milk (FPCM) at the farm gate.

FPCM is calculated with the formula defined by the International Dairy Federation (IDF, 2010):

FPCM (kg/yr) = Production (kg/yr) * [0.1226 Fat% + 0.0776 TrueProtein% + 0.2534].

The approach of the study is from "cradle to gate". The analysis therefore encompasses all the processes needed for the production of 1 kg FPCM milk. The further processing of milk into cheese, the transport and end of life of the cheese are not included in the system boundaries.

Fig. 1 summarises the system boundaries used in this study. Only vitamin supplements, medicines and bull semen are not included, as their overall impacts are considered to be negligible.

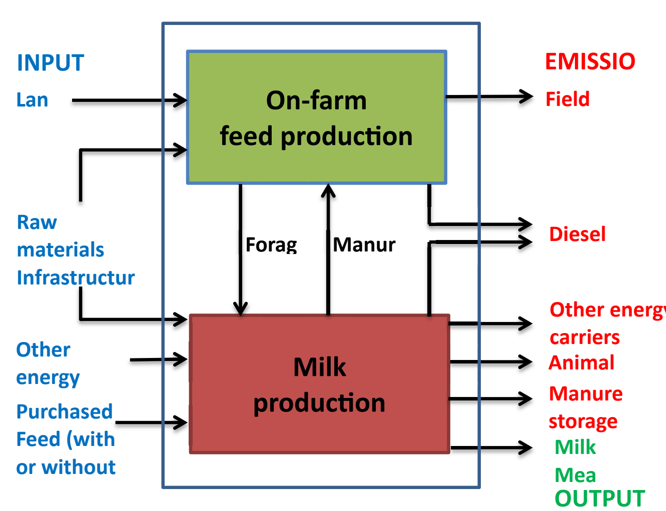

Fig. 1. The system boundaries used in this study.