# Estimating the water footprint of milk produced in the southern region of Brazil

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**ABSTRACT**

Water use is a hot topic worldwide in sustainability assessment. However, this issue is not well evaluated in traditional life cycle assessment (LCA). On the other hand, water footprint (WF) is a methodology that has been developed to give a more complete overview in the water use of particular products (Hoekstra et al. 2011). In this sense, this study evaluated the blue and green WF of three different milk production systems in the southern region of Brazil. To calculate the WF we based on primary data and several data from literature. The results showed that milk from confined feedlot, semi-confined feedlot, and pasture-based systems had blue WF of 19, 11, and 7 liters/kgECM, respectively, and green WF of 1478, 2209, and 1584 liters/kgECM, respectively. We could conclude that higher pasture productivities and/or feed conversion ratio should be sought in all systems, in order to reduce the green (and overall) WF.

Keywords: milk, water footprint, LCA, Brazil

## 1. Introduction

Water is a renewable resource, although its availability in good environmental quality is an important issue worldwide, especially in dry areas. In this sense, water use becomes an important issue for environmental sustainability. There are several ways to evaluate the environmental sustainability of products, and the most predominant is Life Cycle Assessment (LCA) (Dewulf and Van Langenhove 2006). Even though some efforts have been made in recent years regarding water use impacts in LCA (Bayart et al. 2010; Kounina et al. 2013; Pfister et al. 2009), in most traditional LCA studies it is not well evaluated (Milà i Canals et al. 2009), especially when dealing with food products.

Another environmental sustainability methodology, called water footprint (WF), is able to deal with water use in a more complete way. WF is a methodology that has been developed to give a more complete overview in the water use of particular products (Hoekstra et al. 2011). The combination of LCA and WF for sustainability assessment has already been discussed in literature (Boulay et al. 2013; Jefferies et al. 2012; Milà i Canals et al. 2010; Milà i Canals et al. 2009).

Milk is a product from the agricultural sector, which has (as any other product) a certain environmental footprint. In this sense, its environmental impacts have been studied in many reports and scientific publications, although not much has been done for milk in Brazil.

A LCA of milk produced in the southern region of Brazil has been recently studied (Léis 2013), but it did not consider water use and water use impacts. Therefore, the objective of this study is to account for the blue and green WF of three different production systems in the southern region of Brazil. In this sense, it can complement the aforementioned study, providing an additional report for a more complete environmental profile of that product.

## 2. Methods

This study evaluated three different milk production systems in the southern region of Brazil (Parana and Santa Catarina states).

The first system is a confined feedlot system, and it is located in the city of Mandaguari, north of Parana state. In this system the cows solely receive animal feed in the trough. The feed is composed by cottonseed, silage, commercial feed concentrate (cottonseeds, maize grains, wheat bran, soybean hulls, premix), hay, minerals, premix and other cattle foodstuffs.

The second system is a semi-confined feedlot system where the cows are fed in the trough and also through grazing. Apart from the grazed material, the feed is composed by silage, citrus pulp (byproduct of the orange juice industry), brewers spent grain (byproduct of the beer industry), commercial feed concentrate (cottonseeds, maize grains, wheat bran, soybean hulls, premix), minerals, premix, forage and other cattle foodstuffs. This system is located in the city of Porto Amazonas, east of Parana state.

In the third system the cows are mainly fed through grazing, but some feed is still provided in trough. This feed is composed by maize, soybean meal and mineral salts. This system is located in Campos Novos, central region of Santa Catarina state.

The functional unit was 1 kg of energy corrected milk (ECM) at the farm gate. The life cycle inventory was based on Léis (2013), in which a LCA was performed with focus on other environmental impact categories, as eutrophication and carbon footprint.

We calculated the WF based on Hoekstra et al. (2011). For blue water we considered estimations of animal water consumption, based on Araújo et al. (2011), which elaborated an equation of water consumption based on dry matter consumption, milk production, salt consumption, and minimum daily average temperature. We also accounted for the consumption of water from cleaning processes at dairy farms, based on Guerra et al. (2011), considered to be $25L/m^2$. With that, and knowing the area used for milk production in all three systems, we were able to calculate the direct use of blue water. For the indirect consumption of blue water, i.e., the blue water consumed to produce the feed ingredients, for instance, we used data based on literature (mainly the ecoinvent (2010)).

None of the ingredients consumed by the cows were considered to be produced in irrigated systems. According to IBGE (2006), in Brazil only 8% of cotton, 6% of maize, 4% of soybean, and 7% of barley are produced in irrigated systems. Therefore, due to representativeness, we assumed that those products were produced in non-irrigated systems.

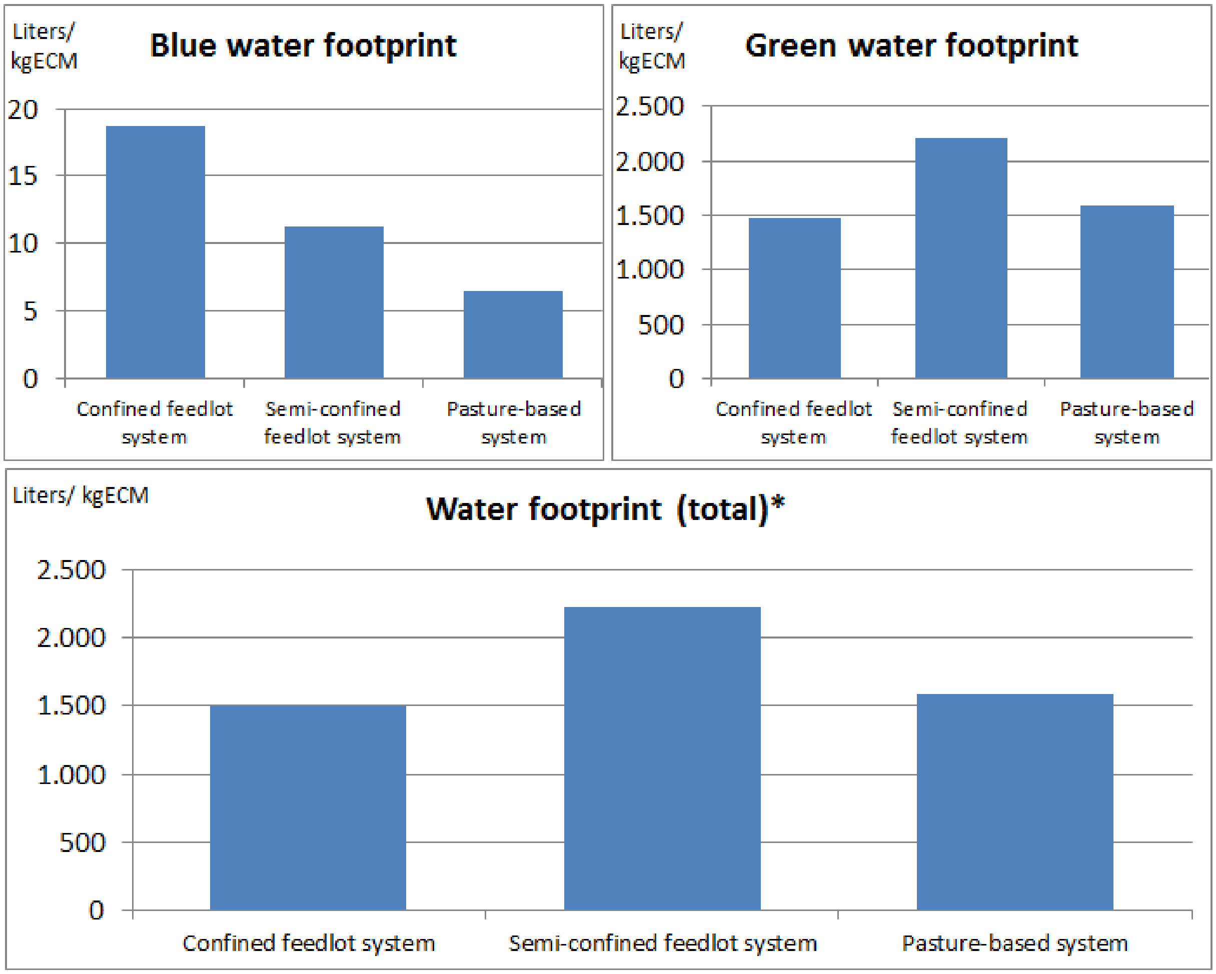
For green water we accounted the water content of the feed ingredients and grass (from grazing), based on data from literature (Brehmer 2008; Phyllis 2011). We also accounted for the water evapotranspired by these feed ingredients and grass (from grazing), also based the data on several other studies, which were from other areas of Brazil due to lack of available data and also lack of information on the origin of the feed ingredients: (1) For maize the evapotranspiration data was based on Albuquerque and Resende (2009); (2) for grazing the evapotranspiration data was based on Uda (2012); (3) for soybean the evapotranspiration data was based on Oliveira et al. (2011); for wheat the evapotranspiration data was based on Paiva et al. (2011); (4) for barley the data was based on Rodrigues et al. (2005); and for cotton the data was based on Pereira et al. (2013).

Even though the water footprint also considers gray water, we preferred to focus on green and blue water in this study, since the two latter represent the water consumed, the aspect that lacks on Léis (2013). Gray water represents rather an emission, and we think that other impact categories in the LCA study from Léis (2013) can better represent environmental impacts (e.g. eutrophication potential).

## 3. Results and Discussion

The results showed that milk from the confined feedlot, semi-confined feedlot, and pasture-based systems had blue WF of 19, 11, and 7 liters/kg ECM, respectively, and green WF of 1478, 2209, and 1584 liters/kg ECM, respectively (Figure 1). These results showed that semi-confined feedlot milk had the highest total WF, due to higher green WF results. This was mainly due to the high amount of brewers spent grain (byproduct of the beer industry) and maize in the feed composition.

Considering that blue WF is the traditional way to account for water use in LCA, it is interesting to note that even though confined feedlot milk had the highest blue WF, the bottleneck on (total) WF was found in the green water, with much higher results than blue WF. Therefore, a traditional LCA could have pointed out different conclusions from WF, as showed in this study (in traditional LCA confined feedlot milk would be the worst system for water use, while in WF system the semi-confined feedlot is the worst system).




* Except for gray water footprint

Figure 1. Blue water footprint, green water footprint, and the total water footprint for three milk production systems from southern region of Brazil.

Mekonnen and Hoekstra (2010) accounted for the green, blue and gray WF of several animal products from several countries. For milk produced in Brazil, the values ranged from 22-42 liters/kg of milk for blue WF, while for green WF the values ranged from 1046-1254 liters/kg of milk. It is possible to observe that the values for blue WF are similar to our system A, although it can be considered much higher when compared to our systems B and C. On the other hand, the green WF from our research (the three systems) are higher than from the values presented in Mekonnen and Hoekstra (2010). Our system A and C had values up to 51% higher, while system B had values up to 111% higher. The reasons for these discrepancies might be differences in amount of feed consumed (blue WF), percentages of feed consumed from irrigated systems (blue WF), amount of grazed land area (green WF), but also differences in evapotranspiration values, differences in the system boundaries considered, uncertainties on data collection, among others. The values presented in Mekonnen and Hoekstra (2012) and Mekonnen and Hoekstra (2010) for global average WF were between 790 and 1087 liters/kg of milk, for green WF, and between 49 and 82 for blue WF. Comparing our values with World average, we can see that blue WF were lower in our research, while our systems had higher values for green WF. The reasons for these differences can be the same as presented before, but for green WF it may also be due to climatic differences (e.g. higher temperatures in Brazil cause higher evapotranspirations).

The expansion of the system boundaries seems to be an important step on the WF methodology. For instance, the system boundaries for background blue WF can be exhaustive, if using life cycle inventory (LCI) databases (as ecoinvent database). On the other hand, the system boundaries have to be consistent among the different WF, and so far there is no LCI database that provides data on green or gray WF, most probably due to the complexity and local specificities of their calculations.

## 4. Conclusion

In this work we estimated the blue and green WF of three milk production systems in southern region of Brazil. Even though most of the data used to calculate the WF was based on secondary data, it was possible to observe possible hotspots (increase productivities of grains used in feed and/or feed conversion ratio), and to identify the systems with lower WF.

This was one of the first studies that published data on WF of milk production systems in Brazil. In comparison to other data from literature, we could observe that our values were higher for green WF, while blue WF had much lower results. These differences could be due to low amount of irrigated crop production systems considered, due to uncertainties on data collection, among other reasons.

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