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IMPACT OF DAIRY EFFLUENT MANAGEMENT IN THE GREY WATER FOOTPRINT

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ABSTRACT: The aims of this study were to assess the grey water footprint in South America dairy systems and analyzed the impact of effluent characteristics and environmental legislation on water footprint value. Grey water footprint quantifies freshwater pollution by the amount of water needed to re-dilute polluted freshwater back to an accepted national threshold value. Water footprints were determined collecting primary data in 61 farms of Argentina (Buenos Aires and Santa Fe provinces) and 20 dairies in Chile. The study considerate total phosphorus in the effluent and the production system as a no-point source of pollution. Phosphorus effluent concentration varied from 0.005 kg m^3 to 0.686 kg m^3 between farms. Chile had the highest phosphorus concentrations and Buenos Aires region the lowest, which could be related mainly to effluent management practices. Grey water footprint varied from 0.59 L of water kg^{-1} to 1.77 L of water kg^{-1} of milk. The maximum value of grey water footprint was observed with dairy slurry with the highest value to phosphorus concentration. Grey water footprint of dairy production will be less per unit of milk as milk production increases. It was observed in the results. The concentration of the element in the effluent, the element used to calculate grey water and the environmental law has a significant impact on footprint values.

Keywords: effluent, no-point, phosphorus.

INTRODUCTION

The amount of water that is used in animal agriculture influences society's view of its environmental sustainability. A response has been a call to increase food production from existing farmland in ways that place far less pressure on the environment and that do not undermine our capacity to continue producing food in the future. Professionals should promote animal systems that improve nutrient and water efficiency, and are resource-conserving.

Grey water footprint quantifies freshwater pollution by the amount of water needed to re-dilute polluted freshwater back to an accepted threshold value. Vanham and Bidoglio (2013) fertilizer-related freshwater pollution is particularly important in the frame of surface and groundwater protection measures and the grey water footprint is a suitable impact quantifier in this regard.

Because local primary data for water footprint calculations is difficult to obtain, most authors use literature data. Witmer and Cleij (2012) indicate that the local context is essential for making the water footprint approach useful for water policies. Up to know there are few studies published about grey water footprint on dairy farm systems in Latin American countries.

Willers et al. (2014) state that there is a need to identify critical points in the production process. This attitude contributes towards the development and implementation of good production practices in such places raise awareness to achieve the best efficiency in the process and reduce potential environmental impacts.

The aims of this study were to assess the grey water footprint in South America dairy systems and analyzed the impact of effluent characteristics and environmental legislation on water footprint value.

MATERIAL AND METHODS

To assess the water footprint accounting for dairy systems, the methodology published by Hoekstra et al. (2011) was used. Grey water footprint was determined collecting primary dairy productive data in 61 farms of Argentina (Buenos Aires and Santa Fe provinces) and 20 dairies in Chile (Southern regions). This farms were randomized selected and do not represent a statistical survey.

The years of reference to countries were different for the examined systems. Details of each farm were based on process data from site visits, bookkeeping data, and dialogue with property managers. Farms size in terms of number of cows, volume of effluent, total phosphorus nutrient load, and milk production are present in Table 1.

The grey water represents a hypothetical quantification of water pollution. To calculate grey water, it is necessary to set the pollutant under consideration. For this study calculation were based on total phosphorus coming from dairy effluent. Effluent was considered water to cleaning and disinfection of milking parlors (cleaning of waste, udders, tools and equipment, floors, and feces and urine collected from milking yards). The grey water footprint functional unit was L of water kg^{-1} of milk year^{-1}.

The equation for grey water is expressed as:

$$WFGray = \frac{(\alpha \; x \; EFload)/(Cmax - Cnat)}{MilkProduction}$$

where WFgrey, is the grey water footprint (m^3 of water Kg^{-1} milk); α, leaching-runoff fraction was assumed in a Tier 1 approach focusing on a global survey of nutrient leaching and run-off, that, irrespective of climate and soil type, a constant fraction of 3% of the P application rate Mekonnen and Hoekstra (2010); EFload, is the load of element in the effluent (kg m^3); Cmax, is maximum acceptable concentration (kg m^3) with reference to Country Environmental Legislation, the threshold of Total Phosphorus to Chilean superficial water is 10 mg L^{-1} in Argentina is 10 mg L^{-1}; Cnat, is natural concentration in a receiving water body (kg m^3), in this study considered as zero for the element; MilkProduction, is the production of milk by the system (kg year^{-1}).

In this study the leaching and run-off of chemical fertilizers and agro-chemicals in crops weren´t taken into account.

RESULTS AND DISCUSSION

South America dairy farms are predominantly grazing-based systems supplemented with varying amounts of off-farm grain-based concentrates. But there are also dairy cows confined to barns for a substantial part of the year and principally rely on homegrown harvested forage and to a lesser extent grains. It must be recognized that Chilean and Argentine herds, feed and water management practices differ, causing the composition of the effluent to be different. According to Mekonnen and Hoekstra (2012) the water footprints of animal products vary greatly across countries and production systems.

Phosphorus effluent concentration varied from 0.005 kg m^3 to 0.686 kg m^3 between farms, indicating that site-specific effluent management influences the element concentration, so this management is key to minimize the load of the element disposed in the soil and the grey footprint. Jarvis et al (2011) the magnitude of P loss pathways will largely be determined by system characteristics such as livestock management and housing, P fertilizer rates and timing, soil conditions, and manure collection and application practices. Wilcock et al. (2006) reported that intensive agricultural practices, such as intensive dairy is generally regarded as high risk for P losses to rivers, because of wrong manure management. On dairy production, grazing systems have a larger green water footprint but in total, industrial systems have a larger water footprint because these systems employ a bigger amount of water resources to dilute pollutants, increasing the grey water footprint (Mekonnen and Hoekstra, 2012).

Chile had the highest phosphorus concentrations and Buenos Aires province the lowest, which could be related mainly to effluent management practices, where in Buenos Aires farms effluents characterization comes from a treated effluent with solid separation, which is expected to have lower P concentration. Comparisons made between effluents characterizations from different geographical regions are most informative if will not be complemented with operational details. In this study nutritional management aspects of each farm was not considered, but large ratio concentrate/roughage in the feed is a factor that can increase the effluent nutrient load. Cerosaletti et al. (2004) reduce the percentage of concentrate in the dry matter intake could generate effluent with lower nutrient load. South America region is intensifying its dairy systems; in general, intensification is accompanied by decreasing dependence on open-range feeding and increasing use of concentrate feeds.

The volume of water to clean the system is also a factor that differentiates the farms. The mean of effluent produced in Chilean farms per milking cow was 61 L day^{-1}. This value was 88 L day^{-1} to Buenos Aires province and 43 L day^{-1} to Santa Fe.

Values of grey water footprint are presented in Figure 1. The lowest mean value was 0.59 L of water kg^{-1} of milk and the highest 1.77 L of water kg^{-1} of milk. The values found in this study are much lower than cited by Sultana et al. (2014) for both countries. Mekonnen and Hoekstra (2012) reports values from 49 to 82 for dairy systems, but they calculated grey water footprint considering only leaching and runoff from crops areas. They did not consider the manure/effluent from the systems. The maximum value of grey water footprint was observed with dairy slurry with the highest value to phosphorus concentration in the effluent 0.69 kg m^3. When treatment systems are used a low proportion of P remains in the slurry and it will have a lower grey water footprint.

Gunduz (2015) a particular consequence of reduced water availability is observed in the reduced dilution capacity of natural systems and increased effects of wastewater discharges on inland waters with particular reference to organics, dissolved oxygen, inorganic parameters, and priority pollutants. To decrease the grey water footprints values waste and effluent managements are important, but the approach should consider the production system, mainly the nutritional management. In this way, the decrease will be easier and cheaper, because the quality and quantity of wastes and effluents are a consequence of what cows are eaten. This approach will also have positive contributions to economic viability and environmental quality.

Grey water footprint of dairy production will be less per unit of milk as milk production increases. It was observed in the results. Farm with the highest milk production per year had a water footprint of 3.69 L of water kg^{-1}. This value is 42% lower than the highest footprint that occurred in a Farm with a milk production 60% lower. In a recent global analysis of the dairy sector (Gerber et al., 2011) less GHG emissions occurred in intensive dairy production systems because cows have higher genetic potential, are fed higher quality diets and have high milk production than in less intensive systems. To increase the milk production in a dairy system the most important thing is improve the transformation of dry matter in product. Sometimes, farmers and professionals opt to buy more cows. It can increase the total milk production, but the system efficiency may continue be low. Consequently, the footprint will be high.

Grey water results should be analyzed considering the environmental law of each country. The concentration of the element in the effluent, the element used to calculate grey water and the environmental law has a significant impact in footprint values. It demonstrates the importance of calculations with a regional focus and the impact that element choice could have. Researches should be promoted to explore the relationship between grey water and feed and waste management's and to evaluate wastewater treatment systems and the impact on footprint values.

CONCLUSIONS

Highest values of gray water footprint were related to high concentration of P in dairy slurry from management systems without separation of solids. Therefore, these slurries have the highest potential for water pollution. If they are properly applied in the soil it will reduce the environmental risk. Few studies calculated grey water to dairy considering the manure/effluent contribution. The lower data found in this study can be a result of: the low P load in the effluent, leaching-runoff fraction assumed, and the P threshold to Chile and Argentina. Inventory approaches of grey water accounting serve to indicate potential risks of freshwater pollution at the regional scale.

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Table 1. Statistical information of dairy farms.

	Number of Milking Cows			Effluent Volume (m^3 ano^{-1})			Cocentration of Total P in the effluent (kg m^3)			Milk Production (kg $year^{-1}$)		
	Buenos Aires	Santa Fe	Chile	Buenos Aires	Santa Fe	Chile	Buenos Aires	Santa Fe	Chile	Buenos Aires	Santa Fe	Chile
Mean	397	136	304	11135	2129	6593	0,035	0,085	0,192	2222033	604275	2226272
Standard Desviation	381	52	218	11219	1201	5510	0,027	0,054	0,160	2044520	230294	1642408
Maximum	1270	333	900	43006	5383	25559	0,085	0,266	0,686	6477000	1043376	6800000
Minimum	40	75	65	1060	368	1354	0,005	0,031	0,022	204000	231528	380000

*Information from 24 farms in Buenos Aires, 37 in Santa Fe, and 20 in Chile.

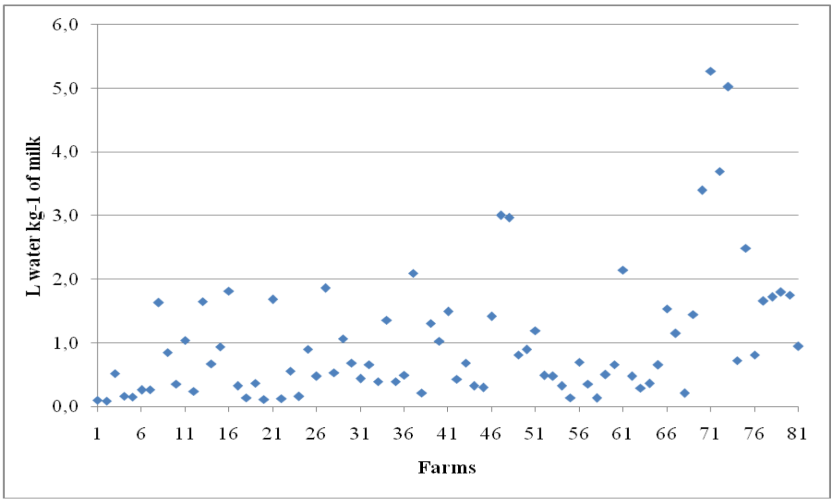

Figure 1. Grey water footprint in the farms.