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# WATER FOOTPRINT OF CONVENTIONAL AND ORGANIC DAIRY PRODUCTION SYSTEMS

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**ABSTRACT:** The aim of this study were to assess the water footprint of both a conventional and an organic dairy production system and identified the components and processes that have the greatest water use in terms of green, blue, gray water, and virtual water. Additionally, it analyzed the impact of element on gray water footprint, and utilized indicators to evaluate the water scarcity. Green water footprint was the most significant contributor to the total footprint values. Virtual water represents from 39% to 57% of footprint value for the conventional and from 32% to 59% for the organic. The consumption of water for irrigation accounted for the greatest percentage of blue water, 95% for conventional and 96% for organic. The element used to calculate gray water footprint has a significant impact on its values. Footprints calculated having phosphorus as element were 1.5 and 1.9 times higher for conventional and organic, respectively. Both conventional and organic farms showed an equal green water scarcity index (1.1) and despite the two farms are located in places with high rainfall, they suffered green water scarcity The blue water scarcity index was 0.11 for conventional and 0.13 for organic. Study concluded that a product with a lower water footprint could be more damaging to the environment than one with a higher water footprint depending on water availability. The water footprint calculations evidenced the relation between animal nutrition and water efficiency. A precise nutritional management reduces green and blue water consumption and nutrient load in the effluent.
**Key Words:** effluent, nitrate, phosphorus, scarcity, water accounting.

## INTRODUCTION

Professionals should promote animal systems that improve nutrient and water efficiency, and are resource-conserving. In this way, production systems will improve resilience and adaptability. The amount of water that is used in animal agriculture influences society's view of its environmental sustainability. Water challenges can no longer be solved within the livestock sector alone because the driving forces and the solutions often lie outside the livestock sector itself. Science and technology are necessary but not sufficient in understanding animal systems changes. Other political, economic, cultural, and ethical factors are also important. Gerber and Steinfeld (2010) multiple and effective options for mitigation exist in the livestock sector that would allow the reversion of current water-depletion trends: reduced water use, reduced depletion, and improved replenishment of the water resources through better land management. The water footprint information can help to reverse these trends, because it produces information about water consumed and the impact of the product in the quantity and quality of water.

The aim of this study were to assess the water footprint of both a conventional and an organic dairy production system and identified the components and processes that have the greatest water use in terms of green, blue, gray water, and virtual water. Additionally, it analyzed the impact of element on gray water footprint, and utilized indicators to evaluate the water scarcity. These were done following a water footprint method compliant with Water Footprint Network (WFN).

## MATERIAL AND METHODS

The frame of reference is the year 2011 (January to December) for both of the examined systems. Details of each farm were based on process data from site visits, bookkeeping data, and dialogue with property managers. The male calves were leaving the farm 40 days after their birth. The lactation period was 305 days with an additional 60 day dry period to both farms. The replacement rate was not considered.

Type of facilities, pasture dry matter yield and its nutritional quality, the quality of concentrate feed, manure management, sources of environmental stress, crop production systems, and quality of workers were very similar between farms. The differences between the systems are in reproductive management and the genetic pattern and sale of animals.

The diets in both farms were formulated for milk yields and seasons and cover most of the production conditions from semi-intensive dairy systems. The ingredients of the conventional dairy diets were pasture, maize silage, soy bean meal, and maize. To organic were the same, replacing maize silage for sugar cane. Systems have a similar pasture irrigated area and the same irrigation system (conventional sprinkler) and water use efficiency (85%).

The green, blue, and gray water footprints were calculated based in Hoekstra et al. (2011).

Standardization was undertaken using the Energy Corrected Milk (ECM) method. ECM was developed to assess all cows on an equal basis for comparative purposes. To handle the co-product beef, the physical approach was followed in order to facilitate comparison with other studies (IDF, 2010).

Water scarcity is defined in this work being the ratio of water use to water availability. The resulting indicators are a measure of the proportion of water resources that have been allocated or are being consumed relative to the availability of water resources. Two indicators were considered to evaluate the impact of water footprints in the geographical areas comprising the conventional and organic systems. United Nations Environment Programme (2012) proposes a green water scarcity indicator. The blue water scarcity indicator provides an indication of the degree of violation or non-violation of environmental flow requirements. Calculation was based in Hoekstra et al. (2012).

## RESULTS AND DISCUSSION

Water footprints values are presented in Table 1. Virtual water calculated based on nitrate represents 57% (456,952 $m^3$/year) of footprint value for the conventional and 59% (199,264 $m^3$/year) for the organic. Based on total phosphorus, virtual water accounted for 39% (450,079 $m^3$/year) for the conventional and 32% (198,345 $m^3$/year) for the organic.

Green water has larger contribution compared to blue and grey water use irrespective of the production systems. Feed production is the largest use of water in a livestock system. This situation can be understood as an opportunity to improve the agriculture water use efficiency and promote the integration between agriculture and livestock. It is necessary to focus on efficient feedstock production and conversion of feedstock into livestock products.

The consumption of water for irrigation accounted for the greatest percentage of blue water. High resource input, predominantly irrigated, has higher impact on blue water resources. These results are important mainly for regions and catchments where there is more competition over blue water. In this situation agriculture should demonstrate the use of resources in an efficient way. Drinking water use rates per year per head were 17.4 $m^3$ and 11.3 $m^3$ per year per head for conventional and organic, respectively. These results show the impact that production system has on blue water demand. Comparisons should be made considering the technological level and management of each system.

Results show the impact that element considered to calculate gray water have in the footprint value and the importance of production system management to generate an effluent with low nutrient load. Gray water results should be analyzed considering the environmental law of each country. In Brazil the effluent total phosphorus concentration allowed to dispose in water sources is restrict. Countries with low total phosphorus daily load should demonstrate similar water distribution between green, blue and gray.

Both conventional and organic farms showed an equal green water scarcity value. It means that systems are using 10% more green water availability to produce feed. This situation did not affect the feed production and milk yield, because both farms used irrigation.

The blue water scarcity indicator was 0.11 for conventional and 0.13 for organic. It means that the conventional dairy farm consumed 11% of available blue water in the reference year and organic 13%. The transition to water stress occurs at 0.2 and moves from stress to scarce at 0.4. Results showed that the farms did not have a stress condition.

Results demonstrated that a product with a lower water footprint could be more damaging to the environment than one with a higher water footprint depending on water availability. The conventional system consumed more blue water than the organic system, at 61,308 $m^3$/year and 39,967 $m^3$/year, respectively. But the conventional farm had more superficial and ground water availability, so the impact of water consumed and footprint was lower.

## CONCLUSIONS

Results demonstrate that care must be taken when analyzing water footprint values. The footprint for each element used to calculate gray water resulted in different interpretations. Furthermore, results represent each production system, so forecasts for other conventional or organic systems should be made carefully considering similar production characteristics. Because of it, results cannot support the consequences in changing the conventional or the organic production system regarding the use of water. The more efficient water use depend on productions factors and water availabilities that are specific to each system. Independently the type of production system, results supports managements that can promote the water efficiency.

This study presents the first water footprint of brazilian dairy using data for specific production systems. It identified resource use and water scarcity indexes associated with two dairy production systems. These highlight the importance of the results to change the actual situation that is to understand water as an abundant input; produce default values that can be use in others studies; and promote a water culture in the livestock science.

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**Tabble 1.** Water footprints of conventional and organic dairy production systems.

| **Green Water** | | |
|---|---|---|
| | Conventional | Organic |
| Pasture ($m^3$/year) | 209,908 (28.9%)[1] | 57,046 (19.7%)[1] |
| Maize to silage (conventional)/Sugar cane (organic) ($m^3$/year) | 61,744 (8.5%)[1] | 34,930 (12.0%)[1] |
| Maize to feed ($m^3$/year) | 372,828 (51.3%)[1] | 153,031 (52.8%)[1] |
| Soybean ($m^3$/year) | 81,457 (11.2%)[1] | 44,942 (15.5%)[1] |
| Volume consumed ($m^3$/year) | 726,142 | 290,005 |
| Green water footprint (L/kg ECM/year) | 884 | 702 |
| **Blue Water** | | |
| | Conventional | Organic |
| Animal drinking ($m^3$/year) | 2,786 (4.5%)[2] | 1,591 (4.0%)[2] |
| Irrigation ($m^3$/year) | 58,523 (95.5%)[2] | 38,376 (96.0 %)[2] |
| Volume consumed ($m^3$/year) | 61,308 | 39,967 |
| Blue water footprint (L/kg ECM/year) | 75 | 97 |
| **Gray Water** | | |
| | Conventional | Organic |
| Volume consumed (nitrate) ($m^3$/year) | 2,959 | 3,546 |
| Volume consumed (phosphorus) ($m^3$/year) | 380,408 | 293,630 |
| Nitrate gray water footprint (L/kg ECM/year) | 3.6 | 8.6 |
| Phosphorus gray water footprint (L/kg ECM/year) | 463 | 711 |
| **Water Footprint (Nitrate)** | | |
| | Conventional | Organic |
| Volume consumed ($m^3$/year) | 790,410 | 333,518 |
| Volume of milk (kg ECM/year) | 770,610 | 308,829 |
| Allocation factor | 0.94 | 0.75 |
| Water footprint (L/kg ECM/year) | 962 | 808 |
| Green water footprint (%) | 91.9 | 87.0 |
| Blue water footprint (%) | 7.8 | 12.0 |
| Gray water footprint (%) | 0.4 | 1.0 |
| **Water Footprint (Phosphorus)** | | |
| | Conventional | Organic |
| Volume consumed ($m^3$/year) | 1,167,859 | 623,602 |
| Volume of milk (kg ECM/year) | 770,610 | 308,829 |
| Allocation factor | 0.938 | 0.747 |
| Water footprint (L/kg ECM/year) | 1,422 | 1,510 |
| Green water footprint (%) | 62.2 | 46.5 |
| Blue water footprint (%) | 5.2 | 6.4 |
| Gray water footprint (%) | 32.6 | 47.1 |
| **Water Scarcity Indexes** | | |
| | Conventional | Organic |
| Green Water Scarcity | 1.10 | 1.10 |
| Blue Water Scarcity | 0.11 | 0.13 |

[1]percentage of green water footprint
[2]percentage of blue water footprint