THE WATER FOOTPRINTING OF LIVESTOCK

An Overview of Water Footprint Studies

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Contents

I. Introduction & Summary of Articles

This Memo contains some of the key information sources being used to influence policy makers and public opinion about the global food industry and its water impact, in particular the impact of the global beef and dairy industry. This purpose of this Memo is to provide a high-level overview of some of the key academic studies and press articles on the subject of the water footprint of beef and dairy, each as summarised below:

Article	Year	Geography	Title/Content
Part III: Dairy Water Footprinting Articles			
a	2014	Global	Benchmarking consumptive water use of bovine milk production systems for 60 geographical regions: An implication for Global Food Security. Global Food Security (*The comparison of this global study enables to identify which farming systems are more efficient than others and how less efficient systems can potentially be improved towards sustainable farming systems to improve food security worldwide. The average Consumptive Water Use per kg of Energy Corrected Milk ranged between 739L on the Danish farm to 5622l on the Ugandan farm with a global average of 1833L*)
b	2014	Global	Comparison of water use in global milk production for different typical farms Agricultural Systems (*Same authors as the above article and similar data, although rather than analysing a combined water use per kg of milk, this study separates the water used in to green and blue water use per kg*)
c	2014	China	Water availability footprint of milk and milk products from large-scale dairy production systems in Northeast China
d	2013	USA	Carbon and water footprint of U.S. milk, from farm to table
e	2010	Germany	Water footprint analysis for the assessment of milk production in Brandenburg – Germany
f	2010	Australia	Short communication: the water footprint of dairy products.
g	2012	New Zealand	Water footprinting – A comparison of methods using New Zealand dairy farming as a case study
h	2013	Holland	Assessing environmental impacts associated with freshwater consumption along the life cycle of animal products: the case of Dutch milk production in Noord-Brabant
i	2010	India	Water footprints of milk production: a case study in the Moga District of Punjab, India
j	2012	Argentina	Water footprint in milk agrifood chain in the subhumid and semiarid central region of Argentina (*Facilitating the convergence between the LCA methodological framework and the implementation of virtual water and water footprint indicators for environmental impact assessments and economic development*)
k	2014	Brazil	Estimating the water footprint of milk produced in the southern region of Brazil (*Higher pasture productivities and/or feed conversion ratio should be sought in all dairy systems, in order to reduce the green (and overall) water footprint.*)
l	2012 & 2013	Britain	The Volumetric Water Consumption of British Milk (*Developed a comparison of metered water use with that estimated using a) a commercial water foot printing tool (Water Footprint Tool, E-CO2 Project) and b) an LCA methodology.*)
m	2015	Belgium	International Dairy Federation on-going work on dairy water footprinting.

Part IV: Beef, Dairy & Soya Water Footprinting Articles			
n	2012	Global	A Global Assessment of the Water Footprint of Farm Animal Products
o	2014	New Zealand	Water footprint of beef cattle and sheep produced in New Zealand water scarcity and eutrophication impacts
p	2012	Global	The water footprint of soya milk and soy burger and equivalent animal products
q	2010	Global	The Green, Blue and Grey Water Foot print of Farm Animals and Animal Products
Part V: Press Articles Influencing Public Opinion & Public Policy			
r	2012	USA/China	Wall Street Journal: virtual water footprint of US dairy feed sent to China
s	2014	USA/China	National Geographic**:** virtual water footprint of US dairy feed sent to China
t	2014	Global	Huffington Post: water footprint of foods compared
u	2009	Global	The Economist: water footprint of grains compared
v	2013	USA	Bloomberg: Soy milk & dairy milk compared on a water footprint basis.

II. Definitions, Terminology & Methodology

The Water Footprint of a product is the volume of freshwater appropriated to produce the product, taking into account the volumes of water consumed and polluted in the different steps of the supply chain.[i]

Blue Water means fresh surface and groundwater; fresh water that can be extracted from lakes, rivers, and aquifers. This includes water extracted from a bore hole or well. [ii]

Green Water means precipitation that is directly used in plant growth, evapotranspiration, or evaporates before becoming ‘blue' water; it does not include the water that falls on crops and runs off into surface water or that recharges ground water. [iii]

Grey Water means an estimate of the amount of clean water needed to dilute any water contaminated by pollutants from the process being analysed, until it is of acceptable quality.[iv]

The main water footprint methods applied to agricultural products are:

i. **Water Footprint Network** (WFN) method, which accounts for the virtual water and is an indicator of direct and indirect freshwater consumption.
ii. **Life Cycle Assessment** (LCA) methods using the ISO standardised framework (ISO 14046, 2010).
   1. One LCA method is based on a stress-weighted water footprint as a function of freshwater scarcity considering hydrological conditions.
   2. A second LCA method is based on potential environmental damages of freshwater consumption to resources, ecosystem quality, and human health.
   3. A third LCA method is based on freshwater use impacts related to the availability of sufficient freshwater for ecosystems, freshwater depletion, and changes in the water cycle caused by land use change. [v]

III. Dairy Water Footprinting Articles

Below are extracts from recent articles and studies on the subject of dairy water footprinting, key messages in each article have been highlighted for ease of review.

a. **Article Citation**: N. Sultana, M. Uddin, B. Ridoutt, T. Hemme & K. Peters, Benchmarking consumptive water use of bovine milk production systems for 60 geographical regions: An implication for Global Food Security. Global Food Security (2014), http://dx.doi.org/10.1016/j.gfs.2014.08.006

   Abstract: This study sets out to measure [consumptive water use] CWU (litre/kg ECM, energy-corrected milk) of typical milk production Systems in 60 dairy regions from 49 countries representing 85% of the world's milk production. The extended version of TIPI-CAL5.2 including water model was used for data analysis. The results have shown the CWU/kg ECM ranged between 739L on the Danish farm to 5622l on the Ugandan farm with a global average of 1833L. When looking at averages per region, the CWU was lowest in Europe (913L) and highest in Africa (3384L) with large intra-and inter-regional differences. Compared with grazing and intensive production system, low yielding cows on small-scale farms have the highest CWU/kg ECM. The key driver for variation in CWU/kg ECM is feed, accounting for 94–99% of the total CWU. Increasing milk productivity might be one of the promising ways to reduce CWU/kg ECM. However, this might also lead to the negative impact into water supply systems if this increase is dependent on land irrigation in water scarce areas. The findings of this study showed the need to address the location of the farm, the feed quality, feeding system and milk production intensity simultaneously when aiming at efficient water resource management which would help to contribute food production and livelihood security of dairy farmers worldwide.

Conclusion: This study highlighted the complexity of measuring CWU in bovine milk production systems of different regions. The results of benchmarking 60 typical farms from 49 countries has shown the average CWU was 1833 L/kg ECM, with a ranged from 913 in Western Europe to 3384 L/kg ECM in Africa. A comparison of different regions revealed that dairy production systems in Asia and Africa demanded higher CWU/kg ECM indicating, that extensive systems based small-scale farms with lower yielding cows demand more water/kg ECM than intensive higher yielding systems. With regards to the input use-related CWU, feed is the single largest contributor to total CWU (i.e., 94–99%). Disaggregated CWU results showed that green water (range: 547–3405 L/kg ECM) clearly dominates over blue (range: 43 and 374 per kg ECM) irrespective of the production systems. Milk yield and feed efficiency is the major driver of productivity and CWU intensities with immense variations between production systems. Feed quality and feed water productivity are sensitive to the CWU that could reduce livestock water demand per liter of milk. The comparison of this global study enables to identify which farming systems are more efficient than others and how less efficient systems can potentially be improved towards sustainable farming systems to improve food security worldwide. Changing production systems patterns to make irrigation service more effective particularly in water scarce area would be future production scenarios for increasing milk production and enhancing food security.

b. **Article Citation**: M.N. Sultana, M.M. Uddin, B.G. Ridoutt & K.J. Peters. Comparison of water use in global milk production for different typical farms Agricultural Systems (2014), http://dx.doi.org/10.1016/j.agsy.2014.05.002.

Abstract: Water use (WU) in dairy production is a matter of discussion all over the world because water scarcity and water pollution are issues of concern in a large number of regions. Concurrently, climate change has also become an emerging concern for most of the dairy producers because this is leading to a change in rainfall patterns and water availability. However, analyses of disaggregated WU in different milk production systems and different countries are scarce. In this context, this study sets out to measure green, blue and grey WU of milk production in 72 dairy regions from 48 countries representing 85% of the world's milk production. This study further considers differences in three milk production systems to explore the causes of variation on WU in milk production. The analysis was based on typical-farm approach representing common production features regionally and different coefficients to convert all the resources used to WU for milk production. The extended version of TIPI-CAL 5.2 (Technology Impact Policy Impact Calculation) model was used for data analysis. The global comparison results of WU has shown the average green, blue and grey WU are 1466, 121 and 106 L/kg ECM, respectively. The lowest green and blue water was found in Western Europe and Oceania with an average of 743 and 44 L/kg ECM, respectively, whereas the highest green water (4549 L/kg ECM) was in African small-scale farms but the blue water (304 L/kg ECM) was highest in Middle East feedlot farms. Meanwhile, the lowest (65 L/kg ECM) and the highest (268 L/kg ECM) grey water was observed in Oceania and Asia, respectively. However, there was a large intra-

and inter-regional differences. Low yielding cows on small-scale farms have the highest WU/kg ECM, followed by grazing and intensive production systems. The determinants for WU variation were mainly due to the interaction effect among the level of production intensity, ration composition, feeding systems and the location where the feed have been cultivated. Feed is the highest single contributor to blue WU accounting for 50–86% of total blue WU depending on farming system. A consequence of using more blue water involves taking water from the environment, meaning it is no longer available for other users or for environmental flows. Although a dairy farmer could increase land productivity by irrigating pasture instead of relying on natural rainfall, the potential increase in environmental harm could be enormous in farms that use irrigation in high water scarce areas.

Conclusion: This study highlighted the methodological complexity of measuring WU in various milk production systems in different regions. The comparison results of WU on 72 typical farms from 48 countries has shown the average green, blue and grey WU in analysed dairy farms are 1466, 121 and 106 L/kg ECM, respectively. The lowest green and blue CWU was found in Western Europe with an average of 743 and 61 L/kg ECM, respectively, whereas the highest green CWU (4549 L) was in low yield small-scale African typical farming but the highest blue CWU (304 L) was in Middle East feed-lot typical farming for kg ECM production. The mean grey WU, the lowest (65 L) and the highest (165 L) was observed in Oceania and Asia farming system for kg ECM production. However, there was a large intra- and inter-regional differences. A comparison of different regions and production system revealed that dairy production systems in Asia and Africa demanded higher CWU/kg ECM indicating that extensive systems based farms with lower yielding cows demand more water/kg ECM than under intensive higher yielding systems in Europe and North America. The farms with higher milk yield/cow, lifetime production, capital and live weight productivity have shown lower WU/kg ECM. Nevertheless, the findings of this study showed that there need composite actions to address inter-actions effect among feeds, feeding systems, milk production intensity and the region of water scarcity where the feed have been cultivated because adjusting various options rather than single effect would only enhance the efficient water resource management and reduce future potential burden on freshwater system. The feed is the single largest contributor to total blue WU (41–86%). A consequence of using more blue water involves taking water from the environment, meaning it is no longer available for other users or for environmental flows. Although a dairy farmer could increase land productivity by irrigating pasture instead of relying on natural rainfall the potential increase in environmental harm could be enormous in farms that use irrigation in high water scarcity areas. This study concludes that it is necessary to reduce pressure on blue WU. This might be possible by increasing efficiency in green WU. This may further reduce costs (either the costs associated with the water and fertilizer or with the energy used to pump water). Water resources are limited and therefore, the farmer needs to use the available water most effectively.

c. **Article Citation**: J. Huang, C. Xu, B. Ridoutt, J. Liu, H. Zhang, F. Chen & Y. Li, Water availability footprint of milk and milk products from large-scale dairy production systems in Northeast China. Journal of Cleaner Production (2014), http://dx.doi.org/10.1016/j.jclepro.2014.05.043

Abstract: As China's dairy consumption grows, both the domestic milk production and the importation of dairy products are increasing to meet demand. As a first step toward understanding the environmental impacts of water use in the expanding Chinese dairy industry, life cycle assessment (LCA) was used to calculate the water availability footprint for large-scale production systems in Heilongjiang, a major production region. Comparisons were also made with imported products from the US (California) and New Zealand. The water footprint of milk (cradle to farm gate) produced in Heilongjiang was around 11 L H2Oe (H2O-equivalents) kg fat-protein-corrected milk (FPCM). This compared to 461 and 0.01 L H2Oe kg FPCM for production in California and New Zealand respectively. ***[READER NOTE: This LCA calculation do not***

include green water used, while the majority of the other studies in this Memo do] Accordingly, the water footprints of milk products (cradle to factory gate) produced in Heilongjiang were much lower than those imported from California, but higher than those from New Zealand. From a food industry perspective, shifting the sourcing of dairy products from California to New Zealand or Heilongjiang could greatly reduce the associated life cycle water footprints of dairy-based processed foods. These results highlight that dairy products can be produced with minimal potential to contribute to freshwater scarcity. However, dairy production systems vary, both in production pattern and local environmental context. With the expansion of dairy farming in China, the development of farming systems with high consumptive water requirements should be avoided in water-stressed regions.

Conclusion: As the first application of LCA-based water footprinting in the dairy industry in China, this study has illustrated that livestock products can be produced with modest potential to contribute to freshwater scarcity. Thus, the generalization that the growing demand for livestock products is the major driving factor for China's water scarcity is not supported in this case. We conclude that it is necessary to examine the regionalized variation in water footprints of all major agricultural commodities as the heterogeneity within sectors is large and the opportunities for water footprint reduction are widespread. This study has demonstrated the large variability in the water footprints between dairy farming systems. As China's domestic milk production is expanding to meet the growing demand, expansion of dairy farming in water-stressed regions should be avoided, unless dairy systems in these areas can predominantly rely on rain-fed crops and pastures. Strategic opportunities also exist for China to reduce its external water footprint associated with dairy products imported from other countries. Food companies such as Mars China can reduce their burden on freshwater systems by sourcing dairy ingredients from regions with low water stress and low water consumption demand. The water footprint of a 43 g Dove® chocolate bar could be greatly reduced by shifting the supply of dairy ingredients from California to New Zealand or Heilongjiang. However, interventions to reduce water footprints should not be taken without due consideration given to the potential consequences for other environmental impact categories (e.g. GHG emissions), as well as social and economic factors.

d. **Article Citation**: Carbon and water footprint of U.S. milk, from farm to table – Special issue, International Dairy Journal (2013) & U.S. Dairy's Environmental Footprint a summary of findings, 2008-2012, Innovation Centre for US Dairy. http://www.usdairy.com/~/media/usd/public/dairysenvironmentalfootprint.pdf.pdf

Explanatory Note: The U.S. Dairy's Environmental Footprint included the summarised findings of the following studies;

- Matlock, M., Thoma, G., Cummings, E., Cothren, J., Leh, M., & Wilson, J. Geospatial analysis of potential water use, water stress, and eutrophication impacts from US dairy production. International Dairy Journal (2012).
- Henderson, A., Asselin, A., Heller, M., Vionnet, S., Lessard, L., Humbert, S. Saad, L., Margni, M., Thoma, G., Matlock, M., Burek, J., Kim, D., and Jolliet, O. U.S. Fluid Milk Comprehensive LCA. University of Michgan & University of Arkansas (2012). This study (*Comprehensive LCA for US Fluid Milk*), completed in 2012, built on the Green House Gases LCA by completing a water footprint for the dairy industry, which establishes a baseline from which to evaluate water quality and availability. Findings will help identify better management practices for dairy farms and businesses.

Water Footprint & Dairy Introduction: Water is a top issue for most industries and organizations worldwide, and the use and quality of water on farms and in milk and dairy processing plants are a significant focus of dairy producers and processors. Analysis of the water footprint of a farm operation or processing plant must take into account local water availability and sources, water stress, and quality of water source. Soil conditions, weather, seasonal changes and management practices add to the mix. The combination of these factors paints a complex water profile that is unique to each facility.

LCA Introduction: The Dairy LCAs focused on water resource impacts from U.S. dairy production, including water use (scarcity) and water quality (eutrophication). Uses of water include irrigation of crops for dairy feed, providing water for dairy cows, and dairy farm operations, such as cleaning. Water quality is an issue when water that contains nutrients and sediment is discharged back to ground or surface water sources. Findings will help the industry understand its water-related risks and opportunities, and to deliver best management practices to help crop farmers, dairy producers, processors and manufactures manage their water footprints.

Key Takeaway: The LCA showed that water use and water quality impacts are location-specific, depending on characteristics of the region and watershed where on-farm dairy and feed production occur. Thus, water use and quality should be measured and managed in a locally-relevant way with practices best suited to the individual operation.

Other Findings:

- The water footprint for milk production is 140 liters of water in competition per kilogram of milk consumed (144.2 gallons of water in competition per gallon of milk consumed)
- The water footprint for cheese is 1.37 cubic meters per kilogram of cheese consumed (164 gallons per pound of cheese consumed) Milk production water withdrawal (excludes thermal power)
- Feed production accounts for more than 90% of water use related to dairy
- Dairy feed irrigation is 4.9% of total U.S. water withdrawal
- On-farm dairy water use is 0.19% of total U.S. water withdrawal
- Total dairy water use is approximately 5.1% of total U.S. water withdrawal

e. **Article Citation**: K. Drastig, A. Prochnow, S. Kraatz, H. Klauss, and M. Plochl, Water footprint analysis for the assessment of milk production in Brandenburg – Germany. Advances in GeoSciences (2010) http://www.adv-geosci.net/27/65/2010/adgeo-27-65-2010.html

Abstract: The working group Adaptation to Climate Change at the Leibniz-Institute for Agricultural Engineering Potsdam-Bornim (ATB) is introduced. This group calculates the water footprint for agricultural processes and farms, distinguished into green water footprint, blue water footprint, and dilution water footprint. The green and blue water demand of a dairy farm plays a pivotal role in the regional water balance. Considering already existing and forthcoming climate change effects there is a need to determine the water cycle in the field and in housing for process chain optimisation for the adaptation to an expected increasing water scarcity. Resulting investments to boost water productivity and to improve water use efficiency in milk production are two pathways to adapt to climate change effects. In this paper the calculation of blue water demand for dairy farming in Brandenburg (Germany) is presented. The water used for feeding, milk processing, and servicing of cows over the time period of ten years was assessed in our study. The preliminary results of the calculation of the direct blue water footprint shows a decreasing water demand in the dairy production from the year 1999 with 5.98×109 L/yr to a water demand of 5.00×109 L/yr in the year 2008 in Brandenburg because of decreasing animal numbers and an improved average milk yield per cow. Improved feeding practices and shifted breeding to greater-volume producing Holstein-Friesian cow allow the production of milk in a more water sustainable way. The mean blue water consumption for the production of 1 kg milk in the time period between 1999 to 2008 was 3.94±0.29 L. The main part of the consumed water seems to stem from indirect used green water for the production of feed for the cows.

Conclusion: The decreased water footprint in Brandenburg over the years from 1999 to 2008 shows that improved feeding practices are more water sustainable than the formerly used feeding practices. But it has to be kept in mind that the assessment of environmental impacts of food production chains must be done under integrative consideration of other kinds of resources used or footprints left. The overall goal should be to produce sufficient high-quality food from the finite resource supply: water, energy, and carbon. The more water sustainable feeding practices may cost a disproportional energy and/or land use input. The incorporation of more detailed data and the incorporation of the indirect water footprint of the feed crop cultivation for the animals of dairy farms in Brandenburg seem to be a promising mean. If the blue water footprint accounts to less than 1% of the whole water footprint, measures to raise water efficiency in milk production should concentrate on green water used during feed production.

f. **Article Citation**: B. Ridoutt, S. Williams, S. Baud, S. Fraval, and N. Marks, Short communication: the water footprint of dairy products. Journal of Dairy Science (2010)

Abstract: In the context of global water scarcity and food security concerns, water footprints are emerging as an important sustainability indicator in the agriculture and food sectors. Using a recently developed life cycle assessment-based methodology that takes into account local water stress where operations occur, the normalized water footprints of milk products from South Gippsland, one of Australia's major dairy regions, were 14.4 L/kg of total milk solids in whole milk (at farm gate) and 15.8 L/kg of total milk solids in skim milk powder (delivered to export destination). These results demonstrate that dairy products can be produced with minimal potential to contribute to freshwater scarcity. However, not all dairy production systems are alike and the variability in water footprints between systems and products should be explored to obtain strategic insights that will enable the dairy sector to minimize its burden on freshwater systems from consumptive water use.

Content: However, compared with carbon footprinting, the science of water footprinting is less well developed. In the dairy sector, LCA studies have either excluded any consideration of water use at all or have included an inventory of water use in dairy farming and dairy product manufacturing without any subsequent assessment of environmental impact (Berlin, 2002; Eide, 2002; Hospido et al., 2003; Capper et al., 2009). Similarly, early attempts at quantifying the water footprints of dairy products, (e.g., 1,000 L/L of milk, 5,000 L/kg of cheese; http://www.waterfootprint.org), building on the concept of virtual water, have reported volumes only. Such volumetric water footprints have been described as potentially misleading and confusing (Ridoutt et al., 2009) because they fail to take into consideration the type of water being used and the local water scarcity where processes occur. For example, the potential harm associated with consumption of so-called green water, derived from natural rainfall over agricultural lands, is not equivalent to so-called blue water withdrawn from surface and groundwater resources. These results [of this report] put the issue of consumptive water use associated with dairy products in an entirely different light compared with the volumetric water footprints mentioned earlier (e.g., 1,000 L/L of milk). We find it hard to see how volumetric water use could be a useful sustainability indicator for dairy products because the type of water used and the local water scarcity where processes occur are factors that must be taken into consideration if the environmental impacts of consumptive water use are to be appropriately assessed. As such, strong caution is given against the public communication of volumetric water footprints. This case study has demonstrated that dairy products can be produced with minimal potential to contribute to freshwater scarcity. That said, not all dairy production systems are alike, and the variability in water footprints between systems and products should be explored in future research. This could lead to strategic insights that enable the dairy sector to reduce its burden on freshwater systems from consumptive water use. Such an approach is likely to be more effective in addressing global water scarcity and food security issues compared with simplistic recommendations to avoid livestock products altogether. Finally, it is important to note that water footprinting focuses on a single issue, namely freshwater scarcity and is not an indicator of overall environmental sustainability. Major strategic decisions should only be taken after considering all of the relevant environmental impacts as well as other social and economic concerns.

g. **Article Citation**: M. Zonderland-Thomassen, S. Ledgard, Water footprinting – A comparison of methods using New Zealand dairy farming as a case study. Agricultural Systems (2012) http://dx.doi.org/10.1016/j.agsy.2012.03.006

Aim of Report: The first goal of this study is to assess the water footprint of NZ dairy farming in two contrasting 'irrigated low rainfall' and 'non-irrigated moderate rainfall' regions. The second goal of this study is to gain insight into differences and similarities between water footprint assessments by applying four methods: (1 water footprint following the Water Footprint Network (WF-WFN), (2 stress-weighted water footprint (WFa-Ridoutt)

Results: the total water footprint of average dairy farm systems in the Waikato and Canterbury regions differentiated by water colour. Total [Water Footprint using the Water Footprint Network methodology] WF-WFN of the Waikato dairy farm system was 945 L H2O/kg FPCM, of which most (72%) was from green water, with grey water at 28% and blue water at only 0.1%. Total WF-WFN of the Canterbury dairy farm system was 1084 L H2O/kg FPCM, of which most (46%) was from green water, with blue water at 23% and grey water at 31%. the [stress-weighted water footprint] WFc-Ridoutt of Waikato dairy farming was 0.011 L H2O-eq/kg FPCM, whereas WFa-Ridoutt was 0.165 L H2O-eq/kg FPCM (Fig. 3). Drinking water and water used at the farm dairy contributed 50% and 42% respectively to total blue water abstracted. WFc-Ridoutt of Canterbury dairy farming was 7.1 L H2O-eq/kg FPCM, whereas WFa-Ridoutt was 11.1 L H2O-eq/kg FPCM. Blue water abstracted for irrigation on-and off-farm contributed 94% while drinking water for animals only contributed 1% to WFa-Ridoutt.

h. **Article Citation**: I. DeBoer, I. Hoving, T. Vellinga, G. VandeVen, P. Leffelaar and P. Gerber, Assessing environmental impacts associated with freshwater consumption along the life cycle of animal products: the case of Dutch milk production in Noord-Brabant Int J Life Cycle Assess (2013)

Abstract: Purpose The assessment of water footprints of a wide range of products has increased awareness on preserving freshwater as a resource. The water footprint of a product was originally defined by Hoekstra and Hung (2002) as the sum of the volumetric water use in terms of green, blue and grey water along the entire life cycle of a product and, as such, does not determine the environmental impact associated with freshwater use. Recently, several papers were published that describe building blocks that enable assessment of the site-specific environmental impact associated with freshwater use along the life cycle of a global food chain, such as the impact on human health (HH), ecosystem quality (EQ) or resource depletion (RD). We integrated this knowledge to enable an assessment of the environmental impact associated with freshwater use along the life cycle of milk production, as a case for a global food chain. Our approach innovatively combined knowledge about the main impact pathways of freshwater use in life cycle assessment (LCA), knowledge about site specific freshwater impacts and knowledge about modelling of irrigation requirements of global feed crops to assess freshwater impacts along the life cycle of milk production. We evaluated a Dutch model farm situated on loamy sand in the province of Noord-Brabant, where grass and maize land is commonly irrigated. Results and discussion Production of 1 kg of fat-and-protein corrected milk (FPCM) on the model farm in Noord-Brabant required 66 L of consumptive water. About 76% of this water was used for irrigation during roughage cultivation, 15 % for production of concentrates and 8 % for drinking and cleaning services. Consumptive water use related to production of purchased diesel, gas, electricity and fertiliser was negligible (i.e. total 1 %). Production of 1 kg of FPCM resulted in an impact on HH of 0.8×10−9 disability adjusted life years, on EQ of 12.9×10−3 m2×year and on RD of 6.7 kJ. The impact of producing this kilogram of FPCMon RD, for example, was caused mainly by cultivation of concentrate ingredients, and appeared lower than the average impact on RD of production of 1 kg of broccoli in Spain.

Conclusions Integration of existing knowledge from diverse science fields enabled an assessment of freshwater impacts along the life cycle of a global food chain, such as Dutch milk production, and appeared useful to determine its environmental hotspots. Results from this case study support earlier findings that LCA needs to go beyond simple water volume accounting when the focus is on freshwater scarcity. The approach used, however, required high-resolution inventory global data (i.e. especially regarding crop yield, soil type and root depth), and demonstrated a trade-off between scientific quality of results and applicability of the assessment method.

i. **Article Citation**: U. Amarasinghe, V. Smakhtin, B. Sharma and N. Eriyagama, Water footprints of milk production: a case study in the Moga District of Punjab, India. (2010) http://hdl.handle.net/10568/39991 and http://www.unep.or.jp/ietc/ws/news-jun10/Session2-2_SriLanka.pdf

Abstract: A project report submitted to Nestle Ltd. under the project measuring the water footprints of milk production: contributions to livelihood benefits and sustainable water use in the Moga District in Punjab, India. This report assesses the water footprints of milk and crop production, their impacts and options of mitigating them. The major objectives of this report are: To assess water availability and use in agriculture in the Moga District of Punjab State, to examine the contribution of the different agricultural water uses to the over all unsustainable water extraction, and its impact on the WFP of milk and crops; To assess surface water and groundwater use of major crops (e.g., rice, wheat and fodder crops) and in milk production, with a focus on feed and fodder and direct water use for dairy cattle; and To propose improved water management practices that farmers can adopt to reduce WFP, and enhance water productivity and conservation, thus contributing to long-term sustainable water use in the region.

j. **Article Citation**: J. Manazza and D. Iglesias, Water footprint in milk agrifood chain in the subhumid and semiarid central region of Argentina (2012) http://ageconsearch.umn.edu/bitstream/126174/2/IAAE%20Water%20Footprint%20Milk%20%20Chain%20Argentina%20.pdf

Abstract: The high agricultural process of the Argentine humid pampas forces the intensification and relocation of cattle and dairy systems into subhumid and semiarid region to keep their competitiveness. In consequence, there is an increasing water demand scenario in these fragile areas in relation with this productive transformation process. Water footprints of UHT milk and cheese agrifood chain in La Pampa and San Luis provinces have been assessed using Life Cycle Assessment (LCA) methodology, including virtual water indicators. Milk chain of La Pampa presents high self-sufficiency water ratio and high primary production proportion in virtual water exports. Water footprint of San Luis milk chain is highly externalized with a low self-sufficiency water ratio.

Conclusions:

- One value of this work is to make contributions to the convergence between the LCA methodological framework and the implementation of virtual water and water footprint indicators for environmental impact assessments and economic development.
- Primary production and particularly the animal feed, is largely the main determinant of Virtual Water indicator for both dairy products analyzed, accounting 99% of its value. In the dairy systems studied, the green water is the main contributing factor to the Virtual Water indicator.

- The results obtained from the analysis of cases in both provinces provide evidence of a negative relationship between productivity per hectare and water footprint, revealing the importance of considering system heterogeneities on water footprint estimates.
- The high values of water costs per unit of output (litre of milk) on dairy systems that use irrigation, show the significant importance of optimizing water use efficiency and maximizing the productivity of the system.
- The analysis of the flow of virtual water and water footprint Dairy Chain in both provinces, identified certain structural characteristics in relation to the use of water resources. Water Footprint of San Luis milk chain is highly externalized, while La Pampa milk chain has a high water self-sufficiency ratio, but strategies for adding value to water productivity are required.
- Further analysis is necessary regarding the redistribution of water between different productive activities to focus on eco-efficiency analysis in a complete and not partial sense. It must involve not only the economic aspects derived from the value and productivity of water, but also all those other things that do not involve strictly socioeconomic productivity like social and environmental factors in all dimensions of impact.

k. **Article Citation**: R. Alvarenga, C. Maria de Léis, E. Cherubini, G. Zanghelini, B. Galindro, V. Prudêncio da Silva Júnior and S. Soares, Estimating the water footprint of milk produced in the southern region of Brazil (2014) http://lcafood2014.org/papers/74.pdf

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.

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.

l. **Study Citation**: T. Hess, J. Chatterton and A. Williams, The Volumetric Water Consumption of British Milk (2012) http://www.dairyco.org.uk/resources-library/research-development/environment/the-volumetric-water-consumption-of-british-milk/#.VF-5JfmG99g and The E-CO2 Project, The volumetric water consumption of British milk: Supplementary study on a sample of 11 dairy farms (2013) http://www.dairyco.org.uk/non_umbraco/download.aspx?media=17328

Abstract: Specific objectives of the supplementary study were to:

- Calculate the ‘blue’ water consumption on 11 dairy farms, making comparisons with recorded metered usage over a 12-month period;

- Apply the methods used by Cranfield in calculating the volumetric consumption of 'blue' water, to real farm data, comparing and contrasting with calculations made using a commercially-available water foot print tool;
- Gain further insight into how water use is apportioned on dairy farms, practically and in the wider context of water foot printing methodology; and
- Make relevant recommendations for improving water use efficiency

Conclusion: Developed a comparison of metered water use with that estimated using a) a commercial water foot printing tool (Water Footprint Tool, E-CO2 Project) and b) the original Cranfield methodology. Metered water consumption varied considerably from farm to farm, reflecting individual circumstances and production system. Calculated water consumption was consistently higher than metered water usage, at least in part, due to the potential for animals to access other sources of water while at grass. Average consumption of 'blue' water, derived from a sample of real farm data using WFT (5.3 per L FPCM) and Cranfield models (6.7 per L Fat and Protein Corrected Milk), were broadly comparable to the theoretical estimates for British milk production, given in the previous Cranfield report (7.4L to 8.1L per kg FPCM).

m. **The International Dairy Federation (IDF)** is working on developing a global methodology for dairy water foot print as we publish this document. But they didn't send us information about that work for the purpose of this publication, therefore it is not included. For more information, contact: http://www.fil-idf.org

IV. Beef, Dairy & Soya **Water Footprinting Articles**

n. **Article Citation**: M. Mekonnen and A. Hoekstra, A Global Assessment of the Water Footprint of Farm Animal Products. Ecosystems (2012). http://dx.doi.org/10.1007/s10021-011-9517-8

Abstract: The increase in the consumption of animal products is likely to put further pressure on the world's freshwater resources. This paper provides a comprehensive account of the water footprint of animal products, considering different production systems and feed composition per animal type and country. Nearly one-third of the total water footprint of agriculture in the world is related to the production of animal products. The water footprint of any animal product is larger than the water footprint of crop products with equivalent nutritional value. The average water footprint per calorie for beef is 20 times larger than for cereals and starchy roots. The water footprint per gram of protein for milk, eggs and chicken meat is 1.5 times larger than for pulses. The unfavorable feed conversion efficiency for animal products is largely responsible for the relatively large water footprint of animal products compared to the crop products. Animal products from industrial systems generally consume and pollute more ground- and surface-water resources than animal products from grazing or mixed systems. The rising global meat consumption and the intensification of animal production systems will put further pressure on the global freshwater resources in the coming decades. The study shows that from a freshwater perspective, animal products from grazing systems have a smaller blue and grey water footprint than products from industrial systems, and that it is more water-efficient to obtain calories, protein and fat through crop products than animal products.

Conclusion: In conclusion, we provide a detailed estimate of the water footprint of farm animals and animal products per production system and per country. The results show that the blue and grey water footprints of animal products are the largest for industrial systems (with an exception for chicken products). The water footprint of any animal product is larger than the water footprint of crop products with equivalent nutritional value. Finally, 29% of the total water footprint of the agricultural sector in the world is related to the production of animal products; one-third of the global water footprint of animal production is related to beef cattle. The global meat production has almost doubled in the period 1980–2004 (FAO 2005) and this trend is likely to continue given the projected doubling of meat production in the period 2000–2050 (Steinfeld and others 2006). To meet this rising demand for animal products, the on-going shift from traditional extensive and mixed farming to industrial farming systems is likely to continue. Because of the larger dependence on concentrate feed in industrial systems, this intensification of animal production systems will result in increasing blue and grey water footprints per unit of animal product. The pressure on the global freshwater resources will thus increase both because of the increasing meat consumption and the increasing blue and grey water footprint per unit of meat consumed. Managing the demand for animal products by promoting a dietary shift away from a meat-rich diet will be an inevitable component in the environmental policy of governments. In countries where the consumption of animal products is still quickly rising, one should critically look at how this growing demand can be moderated. On the production side, it would be wise to include freshwater implications in the development of animal farming policies, which means that particularly feed composition, feed water requirements and feed origin need to receive attention. Animal farming puts the lowest pressure on freshwater systems when dominantly based on crop residues, waste and roughages. Policies aimed to influence either the consumption or production side of farm animal products will generally entail various sorts of socio-economic and environmental tradeoffs (Herrero and others 2009; Pelletier and Tyedmers 2010). Therefore, policies aimed at reducing the negative impacts of animal production and consumption should be able to address these potential tradeoffs. Policies should not affect the required increase in food security in less developed countries neither the livelihood of the rural poor should be put in danger through intensification of animal farming. This study provides a rich data source for further studies on the factors that determine how animal products put pressure on the global water resources. The reported incidents of groundwater depletion, rivers running dry and increasing levels of pollution form an indication of the growing water scarcity (Gleick 1993; Postel 2000; UNESCO 2009). As animal production and consumption play an important role in depleting and polluting the world's scarce freshwater resources, information on the water footprint of animal products will help us understand how we can sustainably use the scarce freshwater resources.

o. Article: M. Zonderland-Thomassen, M. Lieffering and S. Ledgard, Water footprint of beef cattle and sheep produced in New Zealand water scarcity and eutrophication impacts. Journal of Cleaner Production (2014) http://dx.doi.org/10.1016/j.jclepro.2013.12.025

Abstract: There is increasing recognition of the tension between livestock production and freshwater availability. Changes in freshwater availability can be generated by both freshwater consumptive and freshwater degradative use. Agriculture is a major water user, and beef cattle and sheep farming is an importantagricultural activity in New Zealand (NZ). This study assessed potential environmental impacts associated with water use in beef cattle and sheep farming in NZ, following a water footprint method compliant with life cycle assessment principles with a focus on the water scarcity footprint and eutrophication potential (EP) impacts. The life cycle required for the production of beef cattle and sheep was analysed cradle-to-farm-gate, excluding animal transport or processing. Survey data from Beef and Lamb New Zealand for the year 2009/10 were used to cover a range of beef cattle and sheep farm types throughout NZ (426 farms averaged in seven farm classes), and water scarcity footprint and EP weighted averages were calculated for beef cattle and sheep. The normalised NZ weighted average water scarcity footprint of beef cattle of 0.37 L H2O-eq/kg LW was lower than the published normalised values for the water scarcity footprint of beef cattle produced in Australia (3.3e221 L H2O-eq/kg LW) and in the UK. Also, the NZ weighted average water scarcity footprint of sheep of 0.26 L H2O-eq/kg meat (assuming that 40% LW was converted into meat) was lower than the water scarcity footprint of sheep meat

reported for the UK (8.4e23.1 L H2O/kg meat). Blue water losses associated with evapotranspiration from irrigated pasture comprised the greatest proportion of the total water scarcity footprint, despite the small areas of farmland irrigated. The weighted average EP of beef cattle was 51.1 g PO4-eq/kg LW, and the weighted average EP of sheep was 26.1 g PO4-eq/kg LW. The NZ weighted average EP for beef cattle was lower than the 105 g PO4-eq/kg LW reported for European Union suckler beef cattle. On-farm nitrate leaching and phosphorus runoff dominated the EP. From an international marketing perspective, beef cattle and sheep produced in NZ have a potential advantage by having low water scarcity footprints compared to some non-NZ pastoral farming systems due to their production efficiencies and low annual water-stress levels. The impact of NZ pastoral farming on freshwater availability can potentially be reduced by practices that decrease water use, increase feed conversion efficiencies, increase the use of non-irrigated feed supplements, and reduce irrigation. The indicator EP was chosen to enable comparisons with non-NZ studies, but gaseous emissions of nitrogen compounds contributed 33e40% of the total, and their contribution to water pollution is uncertain. This study highlighted the need for a harmonised methodology and as well as to consider specific local contextual information when interpreting the absolute and relative implications of EP results, for example by developing NZ-catchment-specific characterisation factors for aquatic eutrophication in future studies.

Conclusion: This study presents the first water footprint of NZ beef cattle and sheep farming using a life cycle approach and data for specific farm classes. The results indicate that from an international marketing perspective, beef cattle and sheep produced in NZ have a potential environmental marketing advantage due to having lower water consumption than those from pastoral farming systems in other countries that have also been studied with LCA. The results of this study illustrate that the impact of NZ pastoral farming on freshwater availability can be reduced by practices that decrease water use, increase feed-conversion efficiencies, increase the use of non-irrigated feed supplements, and reduce irrigation. Similarly, this study highlights that the potential impact of NZ pastoral farming on water quality can be reduced by efficient nutrient management. This study also identified the need for a harmonised methodology and to consider specific local contextual information when interpreting the absolute and relative implications of EP results, for example by developing NZ catchment-specific characterisation factors for aquatic eutrophication in future studies.

p. **Article**: A. Ercina, M. Aldayab and A. Hoekstraa, The water footprint of soy milk and soy burger and equivalent animal products. Ecological Indicators (2012) http://www.sciencedirect.com/science/article/pii/S1470160X11004110

Abstract: As all human water use is ultimately linked to final consumption, it is interesting to know the specific water consumption and pollution behind various consumer goods, particularly for goods that are water-intensive, such as foodstuffs. The objective of this study is to quantify the water footprints of soy milk and soy burger and compare them with the water footprints of equivalent animal products (cow's milk and beef burger). The study focuses on the assessment of the water footprint of soy milk produced in a specific factory in Belgium and soy burger produced in another factory in the Netherlands. The ingredients used in the products are same as real products and taken from real case studies. We analysed organic and non-organic soybean farms in three different countries from where the soybeans are imported (Canada, China, and France). Organic production reduces soil evaporation and diminishes the grey water footprint, ultimately reducing the total water footprint. The water footprint of 1 l soy milk is 297 l, of which 99.7% refers to the supply chain. The water footprint of a 150 g soy burger is 158 l, of which 99.9% refers to the supply chain. Although most companies focus on just their own operational performance, this study shows that it is important to consider the complete supply chain. The major part of the total water footprint stems from ingredients that are based on agricultural products. In the case of soy milk, 62% of the total water footprint is due to the soybean content in the product; in the case of soy burger, this is 74%. Thus, a detailed assessment of soybean cultivation is essential to understand the claim that each product makes on freshwater resources. This study shows that shifting from non-organic to organic farming can reduce the grey water footprint related to soybean cultivation by 98%. Cow's milk and beef burger have much larger water footprints than their soy equivalents. The global average water footprint of a 150 g beef burger is 2350 l and the water footprint of 1 l of cow's milk is 1050 l.

Conclusion: This study shows the importance of a detailed supply-chain assessment in water footprint accounting. Food processing industries commonly consider water use in their own operations only. If they have water use reduction targets, those targets are formulated with regard to their own water use. With examples for two soybean products, this study shows that, however, the operational water footprint is almost negligible compared to the supply-chain water footprint. For a food processing company, it is crucial to recognize farmers as key players if the aim is to reduce the overall water consumption and pollution behind final food products. Engaging with farmers and providing positive incentives for the adoption of better agricultural practices are an essential element in a food company's effort to make its products sustainable. The results of the study show that the water footprint of a soy product is very sensitive to where the inputs of production are sourced from and under which conditions the inputs are produced. This is most in particular relevant for the agricultural inputs. The water footprints of soy milk and soy burger depend significantly on the locations of the farms producing the soybean and on the agricultural practices at these farms (organic versus non-organic and rainfed versus irrigated). Not only the total water footprint, but also the colour composition (the ratios green, blue, grey) strongly varies as a function of production location and agricultural practice. These results reveal the importance of the spatial dimension of water accounting. For the limited number of cases that we have considered, we find that non-organic soybean has a larger water footprint (ranging between 2145 and 3172m3/ton) than organic soybean (1520–2024m3/ton). Organic agriculture, apart from having a lower evapotranspiration, reduces the grey water component. Shifting towards organic production will reduce the grey water footprint of agricultural production and thus the damage to aquatic life and ecosystems. Another factor that can be influenced is the degree of irrigation. In the case of the two French farms considered in this study, the total water footprint is larger for rainfed soybean, but the blue water footprint of rainfed soybean is zero. The study shows that soy milk and soy burger have much smaller water footprints than their equivalent animal products. The water footprint of the soy milk product analysed in this study is 28% of the water footprint of the global average cow milk. The water footprint of the soy burger examined here is 7% of the water footprint of the average beef burger in the world.

q. **Article**: M. Mekonnen and A. Hoekstra, The Green, Blue and Grey Water Foot print of Farm Animals and Animal Products, Vol 1 UNESCO-IHE (2010)

Abstract: The projected increase in the production and consumption of animal products is likely to put further pressure on the globe's freshwater resources. The size and characteristics of the water footprint vary across animal types and production systems. The current study provides a comprehensive account of the global green, blue and grey water footprints of different sorts of farm animals and animal products, distinguishing between different production systems and considering the conditions in all countries of the world separately. The following animal categories were considered: beef cattle, dairy cattle, pig, sheep, goat, broiler chicken, layer chicken and horses. The study shows that the water footprint of meat from beef cattle (15400 m3/ton as a global average) is much larger than the footprints of meat from sheep (10400 m3/ton), pig (6000 m3/ton), goat (5500 m3/ton) or chicken (4300 m3/ton).

The global average water footprint of chicken egg is 3300 m3/ton, while the water footprint of cow milk amounts to 1000 m3/ton. Per ton of product, animal products generally have a larger water footprint than crop products. The same is true when we look at the water footprint per calorie. The average water footprint per calorie for beef is twenty times larger than for cereals and starchy roots. When we look at the water requirements for protein, we find that the water footprint per gram of protein for milk, eggs and chicken meat is about 1.5 times larger than for pulses. For beef, the water footprint per gram of protein is 6 times larger than for pulses. In the case of fat, we find that butter has a relatively small water footprint per gram of fat, even lower than for oil crops. All other animal products, however, have larger water footprints per gram of fat when compared to oil crops. The study shows that from a freshwater resource perspective, it is more efficient to obtain calories, protein and fat through crop products than animal products. Global animal production requires about 2422 Gm3 of water per year (87.2% green, 6.2% blue, 6.6% grey water). One third of this volume is for the beef cattle sector; another 19% for the dairy cattle sector. Most of the total volume of water (98%) refers to the water footprint of the feed for the animals. Drinking water for the animals, service water and feed mixing water account only for 1.1%, 0.8% and 0.03%, respectively. The water footprints of animal products can be understood from three main factors: feed conversion efficiency of the animal, feed composition, and origin of the feed. The type of production system (grazing, mixed, industrial) is important because it influences all three factors. A first explanatory factor in the water footprints of animal products is the feed conversion efficiency. The more feed is required per unit of animal product, the more water is necessary (to produce the feed). The unfavourable feed conversion efficiency for beef cattle is largely responsible for the relatively large water footprint of beef. Sheep and goats have an unfavourable feed conversion efficiency as well, although better than cattle. A second factor is the feed composition, in particular the ratio of concentrates versus roughages and the percentage of valuable crop components versus crop residues in the concentrate. Chicken and pig have relatively large fractions of cereals and oil meal in their feed, which results in relatively large water footprints of their feed and abolishes the effect of the favourable feed conversion efficiencies. A third factor that influences the water footprint of an animal product is the origin of the feed. The water footprint of a specific animal product varies across countries due to differences in climate and agricultural practice in the regions from where the various feed components are obtained. Since sometimes a relatively large fraction of the feed is imported while at other times feed is mostly obtained locally, not only the size but also the spatial dimension of the water footprint depends on the sourcing of the feed. It is relevant to consider from which type of production system an animal product is obtained: from a grazing, mixed or industrial system. Animal products from industrial production systems generally have a smaller total water footprint per unit of product than products from grazing systems, with an exception for dairy products (where there is little difference). However, products from industrial systems always have a larger blue and grey water footprint per ton of product when compared to grazing systems, this time with an exception for chicken products. It is the lower green water footprint in industrial systems that explains the smaller total footprint. Given the fact that freshwater problems generally relate to blue water scarcity and water pollution and to a lesser extent to competition over green water, this means that grazing systems are preferable over industrial production systems from a water resources point of view. In the case of cattle, pigs, sheep and goats, the total water footprints per ton of product are larger for grazing systems because of the worse feed conversion efficiencies, but the fact that these systems depend more strongly on roughages (which are less irrigated and less fertilised than the feed crops contained in concentrate feed) makes that the blue and grey water footprints of products from grazing systems are smaller. This compensation through the feed composition does not occur for the case of chicken. The reason is that chicken strongly rely on concentrate feed in all production systems. Mixed production systems generally take a position in between industrial and grazing systems. Not accounted for in this study is that industrialized animal production often produces large amounts of animal waste that cannot be fully recycled in the nearby land. Such large amounts of waste produced in a concentrated place are known to pollute freshwater resources if not handled properly. By focusing on freshwater appropriation, the study obviously excludes many other relevant issues in farm animal production, such as micro- and macro-cost of production, livelihood of smallholder farmers, animal welfare, public health and environmental issues other than freshwater.

Conclusion: The present study estimates the water footprint of farm animals and animal products per production system and per country. The results show that:

- Although beef cattle, sheep and goat require much more feed per unit of meat produced than pig and broiler chicken, the fraction of concentrate feed in the total feed is much larger for the latter (Section 3.1). Since concentrate feed has a larger water footprint per unit of weight than roughages (Section 3.2), the water footprints of the different sorts of meat are closer than one would expect on the basis of feed conversion efficiencies alone (Section 3.3).
- The total water footprint of an animal product is generally larger when obtained from a grazing system than when produced from an industrial system, because of a larger green water footprint component. The blue and grey water footprints of animal products are largest for industrial systems (with an exception for chicken products). From a freshwater perspective, animal products from grazing systems are therefore to be preferred above products from industrial systems (Section 3.3).
- The water footprint of any animal product is larger than the water footprint of a wisely chosen crop product with equivalent nutritional value (Section 3.4).
- 29% of the total water footprint of the agricultural sector in the world is related to the production of animal products. One third of the global water footprint of animal production is related to beef cattle (Section 3.5). The global meat production has almost doubled in the period 1980-2004 (FAO, 2005) and this trend is likely to continue given the projected doubling of meat production in the period 2000-2050 (Steinfeld et al., 2006). To meet this rising demand for animal products, the on-going shift from traditional extensive and mixed farming to industrial farming systems is likely to continue. Because of the larger dependence on concentrate feed in industrial systems, this intensification of animal production systems will result in increasing blue and grey water footprints per unit of animal product. The pressure on the global freshwater resources will thus increase both because of the increasing meat consumption and the increasing blue and grey water footprint per unit of meat consumed. Managing the demand for animal products by promoting a dietary shift away from a meat-rich diet will be an inevitable component in the environmental policy of governments. In countries where the consumption of animal products is still quickly rising, one should critically look how this growing demand can be moderated. On the production side, it would be wise to include freshwater implications in the development of animal farming policies, which means that particularly feed composition, feed water requirements and feed origin need to receive attention. Animal farming puts the lowest pressure on freshwater systems when dominantly based on crop residues, waste and roughages. Policies aimed to influence either the consumption or production side of farm animal products will generally entail various sorts of socio-economic and environmental trade-offs (Herrero et al., 2009; Pelletier and Tyedmers, 2010). Therefore, policies aimed at reducing the negative impacts of animal production and consumption should be able to address these potential tradeoffs. Policies should not affect the required increase in food security in less developed countries neither the livelihood of the rural poor should be put in danger through intensification of animal farming. This study provides a rich data source for further studies on the factors that determine how animal products put pressure on the global water resources. The

reported incidents of groundwater depletion, rivers running dry and increasing levels of pollution form an indication of the growing water scarcity (UNESCO, 2009; Postel, 2000; Gleick, 1993). Since animal production and consumption play an important role in depleting and polluting the world's scarce freshwater resources, information on the water footprint of animal products will help us understand how we can sustain the scarce freshwater resources.

V. Press Articles Influencing Public Opinion & Public Policy

One of the most commonly referenced water footprint data sources used in press articles are those listed on the waterfootprint.org website, for example:

r. **Wall Street Journal**, 5 October 2012, P. Culp and R. Gelnnon, Opinion: Parched in the West but Shipping Water to China, Bale by Bale: Exporting water—embedded in alfalfa destined to feed [*dairy*] cattle—is the odd offshoot of tangled, antiquated laws. http://online.wsj.com/articles/SB10000872396390444517304577653432417208116 **Extract**: In 2012, the drought-stricken Western United States will ship more than 50 billion gallons of water to China. This water will leave the country embedded in alfalfa—most of it grown in California—and is destined to feed Chinese [*dairy*] cows. The strange situation illustrates what is wrong about how we think, or rather don't think, about water policy in the U.S. … But the most curious consequence of this export market involves water. Alfalfa is a water-guzzling crop—and the water embedded in the alfalfa that the U.S. will export to China in 2012 is enough to supply the annual needs of roughly 500,000 families.

s. **National Geographic,** 23 January 2014, Exporting the Colorado River to Asia, Through Hay http://news.nationalgeographic.com/news/2014/01/140123-colorado-river-water-alfalfa-hay-farming-export-asia/ **Extract**: When Robert Glennon, a water policy expert at the University of Arizona and author of the book Unquenchable: America's Water Crisis and What to Do About It, first learned that the U.S. was exporting alfalfa crops that had been grown with the very limited western irrigation water, his reaction was "utter disbelief." Glennon crunched some numbers and figured that in 2012, roughly 50 billion gallons of western water—enough to supply the annual household needs of half a million families—were exported to China. Not literally bottled up and shipped, but embedded in alfalfa crops grown with irrigation water. And that's just to China,

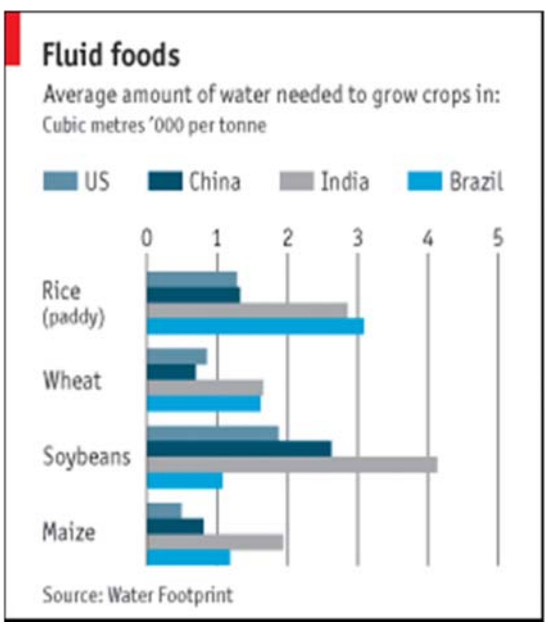
which still trails Japan and the United Arab Emirates as a top destination for American alfalfa. (Use this tool to see how much water is embedded in various farm products.) [**READER NOTE**: this links to a virtual calculator (see image left) which allows readers to calculates the embedded water in everyday food products, the source of the global water footprint of each food product is the Water Footprint Network]

The concept of exporting "virtual water" is not new. And for decades the United States has exported trillions of gallons of it.

According to a UNESCO-IHE Institute for Water Education report published in 2011, the United States exports more than twice as much virtual water, about 82 trillion gallons, as any other country. That's largely because American farms feed the whole world. [**READER NOTE**: One of the leading international academic experts on alfalfa is Dr Daniel H Putnam, Extension Specialist at UC Davis, USA. His critic of the above National Geographic article was posted on the UC Davis blog http://ucanr.edu/blogs/blogcore/postdetail.cfm?postnum=12770]

t. **Huffington Post**, 13 October 2014, This Is How Much Water It Takes To Make Your Favorite Foods, http://www.huffingtonpost.com/2014/10/13/food-water-footprint_n_5952862.html **Extract**: Extensive drought has Californians thinking twice about running the tap while brushing their teeth or taking that 20-minute shower. But what some people don't realize is that a huge portion of our water footprint is "hidden," meaning it's used for the things we eat or wear, and for the energy we use. Globally, agricultural production accounts for 92 percent of our water footprint. In the United States, meat consumption alone accounts for a whopping 30 percent of our water footprint. So exactly how much water do the foods you eat require? Which food would win in a water use showdown? We've got the answers below, along with some helpful hints about reducing the water footprint of your diet. All data come from Water Footprint Network's website and reports on the global average water footprint of different foods. All winners are based on the gallons of water needed to produce a pound of each item or a gallon of each drink.

u. **The Economist**, 8 April 2009, Sin aqua non http://www.economist.com/node/13447271/print



Extract: Different foods require radically different amounts of water. To grow a kilogram of wheat requires around 1,000 litres. But it takes as much as 15,000 litres of water to produce a kilo of beef. The meaty diet of Americans and Europeans requires around 5,000 litres of water a day to produce. The vegetarian diets of Africa and Asia use about 2,000 litres a day (for comparison, Westerners use just 100-250 litres a day in drinking and washing).

So the shift from vegetarian diets to meaty ones—which contributed to the food-price rise of 2007-08—has big implications for water, too. In 1985 Chinese people ate, on average, 20kg of meat; this year, they will eat around 50kg. This difference translates into 390km3 (1km3 is 1 trillion litres) of water—almost as much as total water use in Europe.

v. **Bloomberg**, 20 February 2013, Silk Increases Commitment to Water Restoration and Conservation Efforts http://www.bloomberg.com/article/2013-02-20/aqHm1ecGBd8s.html **Extract**: With drought conditions on the rise across the country, both restoration and conservation projects are crucial to the health of the country's water supply. As a brand committed to environmental sustainability, Silk recently conducted two studies—a "life cycle assessment" and a “water footprint assessment”—comparing the environmental impact of a half-gallon of Silk® Original soymilk, almondmilk and coconutmilk to a typical half-gallon of conventional U.S. dairy milk. (Based on life cycle assessment conducted in 2011 utilizing external LCA experts and certified for comparative declaration under the ISO 14040 /44 standard series and a 2011 water footprint assessment conducted by Silk using the Water Footprint Network methodology and the average annual consumption of Silk and dairy milk by US household.) The independent study, commissioned by Silk’s parent company, WhiteWave Foods, revealed that, on average, producing one half-gallon of plant-based beverages, such as soymilk, almondmilk or coconutmilk, requires 77 percent less water and generates 47 percent fewer greenhouse gases (GHGs) than producing one half-gallon of conventional U.S. dairy milk.

w. The Guardian, 10 January 2013, How much water is needed to produce food and how much do we waste? http://www.theguardian.com/news/datablog/2013/jan/10/how-much-water-food-production-waste
Extract: 255L of water are required to produce one 250ml glass of milk. 1kg of meat requires between 5,000 and 20,000 litres of water.

VI. Conclusions & Further Research

a. How can a consumer benchmark all the various Water Footprint data for dairy and beef?

This Memo showcases numerous methodologies used to calculate the water footprint of dairy and beef, all producing different results. For example New Zealand dairy’s water footprint has at least 4 very different water footprints:

1. [article a] 1,600 L Consumptive Water Use (Litre per Kg of Energy Corrected Milk)
2. [article b] 0-200 L H2O/kg Energy Corrected Milk (Blue Water Use)
3. [article c] 0.01 L H2Oe/kg fat-protein-corrected milk (Blue Water Use)
4. [article g] Total water footprint of 945 and 1084 L H2O/kg fat-and-protein-corrected milk (using the water footprint network assessment for two different regions in NZ)

“Applying different water footprint methods not only complicates comparing results between products and countries, but it also complicates communication to stakeholders and identification of potential mitigation strategies.” [vi] These confusing results helps explain why this Memo’s review of press articles on water footprints of dairy and food (see section *V. Press Articles Influencing Public Opinion & Public Policy*) shows the press uses the simplified consolidated water footprint data published by the Water Footprint Network:

1. [article r] 1,040L of water to produce 1L of milk (National Geographic)
2. [article u] 1L soy milk required 77% less water than 1L of milk (Bloomberg)
3. [article v] 1,020L of water to produce 1L of milk (The Guardian)

The global beef and dairy industries should consider choosing one benchmark and methodology to show and promote its historical improvement in water efficiencies and future water efficiency gains, rather than allowing public opinion and ultimately public policy to be influenced by the overly simplistic (potentially misleading) water footprint calculations which do not distinguish between the use of renewable water sources for the production of dairy and beef.

b. What are the key elements to consider to size real water issues in the world’s dairy supply chains?

1. **Global Improvement**: Given the various emerging methodologies, there is an opportunity for the global beef and dairy industries to agree on one industry approved methodology to be used to calculate a baseline water footprint and then show continual improvement against that baseline. Based on the articles contained in this Memo, article a. (*Benchmarking consumptive water use of bovine milk production systems for 60 geographical regions: An implication for Global Food Security*) appears to be the most appropriate choice for using as the baseline, given its global reach and collaboration with the leading dairy farm data group the International Farm Comparison Network, who would be best placed to reassess on an annual basis the industry’s improvement against that baseline.

2. **Blue Water**: Another key water related issue in the world's beef and dairy supply chains is to understand how much blue water is being used in the production of various beef and dairy products, however, a critical detail about blue water appears to have been missed in all the blue water footprint studies contained in this Memo, which is how sustainable is the blue water being used? Not all blue water is unsustainably used, blue water can be drawn sustainably from lakes, rivers and aquifers that are naturally recharged within (or beyond) the limits of current (and projected) use, while other blue water is unsustainably drawn from catchments/aquifers that are either lacking natural recharge (eg: fossil groundwater) or less recharged than what is current abstraction and ecosystem requirements (overexploited catchments).

   For further reading on this specific issue, see SAI Platform Water Stewardship in Sustainable Agriculture and SAI Platform TB 15 on drip Irrigation.

c. What further research could be carried-out on the water footprint of the dairy and beef industries?

There appears to be little available research on the associated water footprint of the imported feed components used by the global beef and dairy industries, future water footprint related research could be focused on the following areas:

1. **Dairy's Global Alfalfa/Lucerne Hay Trade**: one of the largest 'headline risks' for the water footprint of dairy feed is the production and the global trade flows of alfalfa/lucerne hay, e.g. see above section V (*Press Articles Influencing Public Opinion & Public Policy*), however, little is known about the actual and comparative (to other exported agri commodities or green water hay alternatives) water impact of the global alfalfa/lucerne hay trade.
2. **Beef's Varied Water Footprints:** compare the related water footprints of the major beef production systems globally, to identify the true water risks from beef production, help dispel some of the myths around beef's water consumption and demonstrate the positive role of beef production in the water debate. Such a comparison would require taking into account beef's major feedstock and production systems, i.e. grass-fed and grain-fed (differentiating locally produced and imported feed grains/oil seeds into Europe and Asia). The review should also evaluate rain-fed and sustainably managed irrigated feed crops against those feed sources using less-sustainable irrigated water (from over exploited water catchments) and determine the most water efficient beef production systems and therefore how to improve the least water efficient production systems.

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[i] www.waterfootprint.org accessed on 8 November 2014
[ii] Ibid.
[iii] Ibid.
[iv] Ibid.
[v] Water footprinting – A comparison of methods using New Zealand dairy farming as a case study, Agricultural Systems (2012).
[vi] Ibid