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Benchmarking consumptive water use of bovine milk production systems for 60 geographical regions: An implication for Global Food Security

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ABSTRACT

This study sets out to measure 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-CAL 5.2 including water model was used for data analysis.

The results have shown the CWU/kg ECM ranged between 739 L on the Danish farm to 5622 l on the Ugandan farm with a global average of 1833 L. When looking at averages per region, the CWU was lowest in Europe (913 L) and highest in Africa (3384 L) 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.

1. Introduction

Freshwater is the most valuable resource as this is the precious life-sustaining element in the planet which cannot be substituted by any other element. In reality, freshwater is scarce in many regions of the world and it has been estimated that a third of the world's human population is jeopardized by lack of water to meet daily needs (Rosegrant et al., 2002). Reducing the amount of water that crops use is an important challenge because as pressure on WU rises can increase price of food which eventually decrease access to food and reduce food security. This again hampers the food security policy at national and regional level. Fig. 1 depicts the geographical regions where water is scarce (Pfister et al., 2009).

An increasing world population is coupled with rising food requirements combined with rising per capita consumptive water use (CWU), however, global food production and food security are not directly linked (Rockström et al., 2009). Furthermore, political tensions over access to water and diverting it for dams, canals and irrigation for food production are ongoing concerns between a numbers of countries. Thus, it is critical to ascertain tactics to expand water availability takes a central role in reaching economic, social and environmental goals of sustainable development and increase food production, without it there is no prospect for achieving any of the "Millennium Development Goals" (UNWWAP, 2009).

19% of animal water use is related to dairy cattle production (Mekonnen and Hoekstra, 2010b). However, there is an increasing trend of milk consumption (Thornton, 2010) which instigate to expand dairying much faster than ever before but the water

Abbreviations: CWU, Consumptive Water Use; CP, Crude Protein; ECM, Energy-Corrected Milk; ET, Evapotranspiration; DMI, Dry Mater Intake; DWR, Drinking Water Requirement; FAO, Food and Agriculture Organization; FE, Feed Efficiency; MDG, Millennium Development Goal; IFCN, International Farm Comparison Network; LW, Live Weight; TIPI-CAL, Technology Impact Policy Impact Calculation Model; TFA, Typical Farm Approach; NEL, Net Energy for Lactation; VWC, Virtual Water Content; WU, Water Use; WUE, Water Use Efficiency

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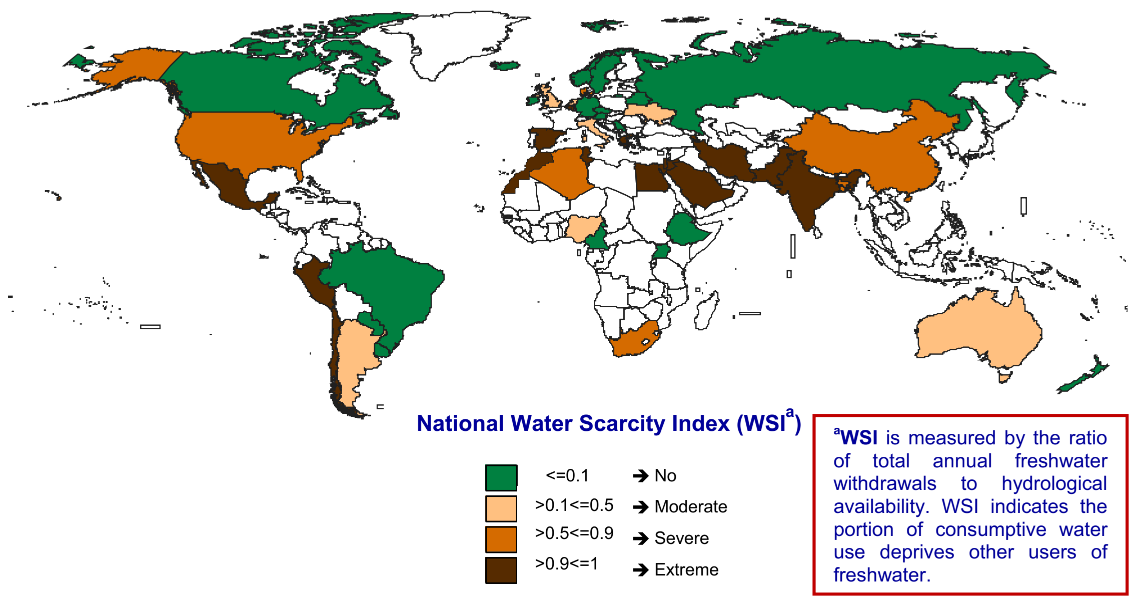

Fig. 1. Holistic view of current water scarcity by region (Modified from Pfister et al., 2009).

scarcity will become a major limiting factor to food security due to possible inter-linkage and competition between the water and the food supply system (Strzepek and Boehlert, 2010). Therefore, decreased water availability is a risk to global food security. Conversely, global food production will have to increase by 50% but only half of the land will be available over current levels to meet demands (FAO, 2010). Decrease water availability along with decrease land availability entail to develop appropriate strategies that optimize CWU efficiency in dairy farming.

To discourse the problems of water scarcity and food security, there is a need for research to develop appropriate strategies that optimize CWU efficiency and increase dairy production without off-setting water resource. The first step to address this interlinks between water and food security is to measure CWU in dairy production because, the assessment of WU of a wide range of products has increased awareness of preserving freshwater as a precious resource (WFN, 2012). A few of studies have documented CWU in milk production, most of them are region specific (Sraïri, 2009; Drastig, 2010) and only very few studies (Chapagain and Hoekstra, 2003; Mekonnen and Hoekstra, 2010b; Ran, 2010) were able to emphasis on global analysis by using secondary data. However, the results from those studies show a high variation, likely due to complications in measuring the CWU for feed production. In order to address the issue of food security in the context of CWU, this study aims at overcoming those limitations by identifying the ways to increase efficiency in CWU in milk production by utilizing system parameters based on detailed farm level data and applying consistent approach in a wide range of farming systems globally. CWU at farm level would be the most worthwhile to assist farmers in understanding CWU efficiency and its optimization by innovative farm management for increasing milk production and food security.

To expand the discussion of CWU of a milk production, it is important not to only quantify aggregated CWU but also assess disaggregated WU. The aggregated CWU (i.e. sum of green and blue) in animal products is potentially misleading and confusing because its use fails to take into consideration disaggregated green and blue WU (Ridoutt et al., 2010b). Hence, the overall goal of this study is to estimate CWU from all types of inputs used in various milk production systems in order to provide an answer to the key question: how many litres of water are required per kg milk in dairy production systems globally and what are the implication of measuring water at farm level on food security? Therefore, the study has envisaged two sub objectives to achieve this goal:

(i) To quantify CWU per kg milk at farm gate by providing detail background information on the geographically-defined typical dairy farming systems in 49 countries.
(ii) To show the implications of how does water use efficiency is linked with food security at global level.

2. Materials and methods

2.1. TIPI-CAL including the water module for data analysis

The study followed the IFCN (International Farm Comparison Network) method which is based on: (i) the typical farm approach (TFA) and (ii) The TIPI-CAL (Technology Impact Policy Impact Calculation) model (http://www.ifcndairy.org/). The main software used for the international comparison to benchmark CWU/kg milk is the extended version of the TIPI-CAL-5.2 model (H_2O module) (Sultana, 2013).

2.2. Selection of typical farm data and functional unit

Typical farm is the basis of our CWU analysis. The underlying typical farm datasets were derived from the typical farms of IFCN network (http://www.ifcndairy.org/). This research analysis was based on 60 geographically standardized typical farms from 49 countries for representing a broad range of farming systems (Appendix Table 1). The farms were selected from 157 typical farms, mainly based on the required data availability and data quality for the analysis of CWU. Detailed analysis was being performed on six case farms from six countries that represent three different production systems (i.e. intensive, grazing and small-scale) in order to investigate the underlying causes of variations on CWU. The production system is defined by the productivity level, feed dry matter intake (DMI), capital and labor intensity and feed efficiency for milk production e.g., the farm characteristic on the individual farm code is presented in Appendix Table 1.

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