Agricultural Systems 129 (2014) 9–21

Contents lists available at ScienceDirect

Agricultural Systems

journal homepage: www.elsevier.com/locate/agsy

Comparison of water use in global milk production for different typical farms

M.N. Sultana [a,b,*], M.M. Uddin [b], B.G. Ridoutt [c], K.J. Peters [d]

[a] Department of Agricultural Economics, Humboldt University of Berlin, Hannoversche Strasse 27, H-12, 10115 Berlin, Germany
[b] Department of Animal Nutrition, Bangladesh Agricultural University, Mymensingh-2202, Bangladesh
[c] Commonwealth Scientific and Industrial Research Organization (CSIRO), Sustainable Agriculture Flagship, Clayton, Victoria 3169, Australia
[d] Department of Plant and Animal Sciences, Humboldt University of Berlin, Philip Strasse 13, 10115 Berlin, Germany

ARTICLE INFO

Article history:
Received 7 January 2013
Received in revised form 7 March 2014
Accepted 5 May 2014
Available online 29 May 2014

Keywords:
Water scarcity
Water use
Water management
International comparison
Typical dairy farming system

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.

1. Introduction

Pressure on freshwater has intensified in recent years not only due to population growth and rising food requirements but also as a cumulative impact of climate change, land cover changes, poor governance in water use (WU), and the development of water diversions. The other responsible factors are socioeconomic development, increasing rate of urbanisation, demand driven by industrial growth, and changes in the agricultural sector (i.e. the expansion of biofuel crops) (Wallace, 2000; Ridoutt and Pfister, 2010). Agriculture requires by far the highest amount of water, accounting for 85% of today's global freshwater consumption (Shiklomanov, 2000) wherein irrigation alone accounts for 70% of all freshwater withdrawals (Ridoutt et al., 2009; WWAP, 2009;

* Corresponding author at: Department of Animal Nutrition, Bangladesh Agricultural University, Mymensingh-2202, Bangladesh. Tel.: +880 1860233242.
E-mail address: nadira_bau@yahoo.com (M.N. Sultana).

http://dx.doi.org/10.1016/j.agsy.2014.05.002
0308-521X/© 2014 Elsevier Ltd. All rights reserved.

FAO, 2010) to produce food for meeting the demand of the ever growing human need (Wallace, 2000). Therefore, the soaring agricultural production in many parts of the globe (e.g. China, India) is causing overexploitation of surface water bodies, depletes groundwater resources and may endanger the freshwater abundance of food production for future generations (Falkenmark and Lannerstad, 2005; Koehler, 2008). It is predicted that by 2050 only 82% of the current water will be available for agriculture worldwide (Strzepek and Boehlert, 2010). According to UNEP (2008), the turning point would be in 2025 when almost half of the world's population would be living in worsening situation of water stress due to increasing WU in both developing (50%) and developed countries (18%), by that time worldwide water demand is expected to be 40% more than today (Brown and Mattock, 2011; Oppenlander, 2011).

At the same pace, livestock production and more specifically dairy production faces great challenges as WU in this sector is also increasing (Khelil-Afra et al., 2012). Livestock production, thus, impacts heavily on the world's water supply, representing > 8% of global human WU (Sharma, 2007; Schlink et al., 2010), 10% of global water flows (Deutsch et al., 2010), and 29% of agricultural WU (Mekonnen and Hoekstra, 2010b). The expansion of global dairy production has a major effect on this trend, and 19% of animal WU is already today related to dairy cattle production (Mekonnen and Hoekstra, 2010b). However, dairying is an important source of human food and an integral part of agricultural production and the social fabric for more than two thirds of the population especially for smallholders in developing countries (Uddin, 2011; Doreau et al., 2012). Thus, there is an increasing trend of milk consumption (i.e. 34–78 and 195–216 kg annual per capita consumption during 1980–2050 in developing and developed countries, respectively) and an increasing cattle number to meet demand (Thornton, 2010). This instigates to expand dairying much faster than before but the water scarcity has to impart challenges to food security due to possible inter-linkage and competition between the water and the food supply system (Strzepek and Boehlert, 2010).

It is also interesting to see the existing relation between global milk production and water scarce regions on typical farming systems. The global milk production volume (Hemme et al., 2011) and water scarce areas by Water Stress Index (Pfister et al., 2009) are depicted in Fig. 1 in order to show the water scarcity situation worldwide. This figure shows that some areas are extremely water scarce and when it is combined with high milk production, it can be argued that water might be a threat to milk production. However, there are also interregional differences of water scarcity within country. This interaction implies that future milk production can be under threat due to shortage of water unless significant WU management strategies are implemented.

Moreover, intensification of dairying has ameliorated the current water consumption pattern towards a more vulnerable WU pattern. This is the basis for the arguments to increase intensification of dairying in order to boost farm productivity (Alvarez et al., 2008; Alvarez and del Corral, 2010; Udo et al., 2011) and Water Use Efficiency (WUE). In addition, there is a widely held view that 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). This also leads to demand for vast amounts of irrigation water for soaring dairy production (e.g. India, Western USA). Thus, appropriate strategies that optimise WUE in dairy system are needed. It is important to identify ways to expand dairy production without contributing to water scarcity at the local level.

To address the problems of water scarcity and intensification, there is a need for research how to increase dairy production without off-setting water resource. The first step is to tackle the situation is to measure WU in dairying. In this study, WU refers to both consumptive (i.e. green and/or blue water) and polluted water (i.e. using water as a medium of wastes, water pollution). Although several studies have documented WU per kg milk, most of them are based on aggregated consumptive water use (CWU) and region specific (SraÏri et al., 2009; Drastig et al., 2010) and very few studies (Chapagain and Hoekstra, 2003; Mekonnen and Hoekstra, 2010b; Ran, 2010) were able to focus on global analysis by using secondary data. Also, the analysis of water types using consistent methods that enable comparability across the dairy farming systems is lacking.

Recent discussions of the WU in animal products showed that the aggregated WU (i.e. sum of green, blue and grey water) is potentially misleading and confusing because it fails to take into consideration the type of water being used and the location of production where it occurs (Ridoutt et al., 2010). The aggregated water volume is, therefore, does not yield informative to the environmental impact assessment of freshwater use (Ridoutt et al., 2010; de Boer et al., 2013). The reason is that types of water use are helpful in understanding the environmental impact from each type of water use. The recent research on environmental impact found that blue water has more impact to the environment (de Boer et al., 2013) although Zonderland-Thomassen and Ledgard (2012) argued that green water is also important to include for environmental impact assessment of a product. However, abstraction of water for farming leading to drying up canals and rivers, polluted water ways and also reducing ground water tables (Mwakalila, 2011) these means blue water has taken from the environment and this resource is in limited supply. On the other hand, green water does have the same impact like blue water does (Ridoutt et al., 2010). Therefore, to extend the analysis, this research aims not to only quantify aggregated water volumes but also to assess types of water is being used in the typical dairy farming systems globally. In this regards, the study has envisaged the following goals:

(i) To quantify and compare the different types of WU in international milk production systems.
(ii) To identify the underlying drivers that explain regional variability and their relative importance and thereby affecting water availability in milk production.

2. Materials and methods

2.1. Selection of typical farms and data collection

The selection of typical farms and data analysis involves four basic steps which are depicted in Fig. 2. In 1928 Elliot defined a typical-farm as being "a model farm in a frequency distribution of farms of the same universe; or it is representative of what a group of farmers are doing who are doing essentially the same thing" (Dillon and Skold, 1992). A typical-farm represents the most common farming system, farm size, production technology used; expressed average management practiced and produced a high proportion of milk in the dairy regions/country. The underlying farm datasets were derived from the typical farms of IFCN (International Farm Comparison Network) network (http://www.ifcn-dairy.org/). The data collection and data validation to fulfil objectives of this study were done following a Panel Approach which is comparable to a "Modified Delphi Technique" (Custer et al., 1999). In this study, for each country one or more standardised typical farms were modelled to cover a broad range of production systems. This analysis was based on 72 typical farms from 48 countries. The farms were selected from 157 typical farms, mainly based on the required data availability and data quality. The descriptive statistics for key parameters on selected farms are shown in Table 1. There is a significant variation with regard to