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Water footprinting of dairy farming in Ireland

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ABSTRACT

In the context of global water scarcity, water footprints have become an important sustainability indicator for food production systems. To improve the water footprint of the dairy sector, insight into freshwater consumption of individual farms is required. The objective of this study was to determine the primary contributors to freshwater consumption (i.e. water use that does not return to the same watershed) at farm-gate level, expressed as a water footprint, for the production of one kg of fat-and-protein corrected milk (FPCM), on 24 Irish dairy farms. This is the first study that uses detailed farm level data to assess the water footprint of a large set of Irish dairy farms. The water footprint comprises of the consumption of soil moisture due to evapotranspiration (green water), and the consumption of ground and surface water (blue water), and includes freshwater used for cultivation of crops for concentrate production, on-farm cultivation of grass or fodder and water required for animal husbandry and farm maintenance. The related impact of freshwater consumption on global water stress from producing milk in Ireland was also computed. Over the 24 farms evaluated, the production of milk consumed on average 690 L water/kg FPCM, ranging from 534 L/kg FPCM to 1107 L/kg FPCM. Water required for pasture production contributed 85% to the water footprint, 10% for imported forage production (grass in the form of hay and silage), concentrates production 4% and on-farm water use ~1%. The average stress weighted water footprint was 0.4 L/kg FPCM across the farms, implying that each litre of milk produced potentially contributed to fresh water scarcity equivalent to the consumption of 0.4 L of freshwater by an average world citizen. The variation of volumetric water footprints amongst farms was mainly related to the level of feed grown on-farm and levels of forages and concentrates imported onto the farm. Using farm specific data from a subset of Irish dairy farms allowed this variability in WF to be captured, and contributes to the identification of improvement options. The biggest contribution to the water footprint of milk was from grass grown with green water, which is a plentiful resource in Ireland. This study also indicates an opportunity for present and future milk production systems to source feed ingredients from non-water stressed areas to further reduce the burden on freshwater resources, especially in countries that utilise confinement systems that have a higher proportion of concentrate feed in the dairy cow's diet.

1. Introduction

Sustainable production of animal-source food has re-emerged at the top of the political agenda for two reasons, 1; demand for animal-source food will rise due to the increasing global population, rising incomes and urbanization (FAO, 2009; Steinfeld et al., 2006; Wirsenius et al., 2010), 2; the challenge to produce animal-sourced food in a resource efficient manner (Aiking, 2014; Johnston et al., 2014; Steinfeld et al., 2013). There is increasing recognition of the tension between livestock production and water use (Busscher, 2012; Molden et al., 2011; Ridoutt et al., 2014), hence understanding the distribution and demands for freshwater in livestock production are of particular importance. Finite freshwater availability could become the main limiting factor for the global growth of the agri-food sector (UNEP, 2007). Quantifying the water

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footprint (WF) of agricultural outputs and identifying hot spots of water consumption along the food chain, therefore, is a first step in reducing the pressures on freshwater systems resulting from livestock production, while at the same time providing end user information.

Irish livestock production systems do not suffer water shortages or droughts due to Ireland's temperate maritime climate (Kottek et al., 2006). However, increasing the sustainability of milk production by reducing consumption of resources, such as water, will improve the marketability of Irish dairy exports (DAFM, 2010). The Irish dairy industry produces approximately 5.4 billion litres of liquid milk (0.7% of global production) and exports 85% of its annual production (DAFM, 2012). Moreover, Irish milk production is going through a period of rapid expansion due to the abolition of European Union (EU) milk quotas. This expansion is being supported by the Irish government who have identified the potential for an increase in output of up to 50% up to 2020 (DAFM, 2010).

To gain insight into the water use of Irish dairy farms, from cradle to farm-gate, the water footprint can be quantified, defined by the Water Footprint Network (WFN) as the sum of the volumetric water use along the entire supply chain of a product (Hoekstra et al., 2011). This water footprint comprises of the consumption of soil moisture due to evapotranspiration (green water), the consumption of ground and surface water (blue water), and the degree of freshwater pollution due to wastewater discharges (grey water) (Hoekstra et al., 2011). While green and blue water represent consumed water, grey water represents an emission. It has been argued, therefore, that grey water can be better represented in a life cycle assessment (LCA) (Jefferies et al., 2012; Milà i Canals et al., 2009; Pfister et al., 2009). Furthermore, volumetric water footprints alone highlight the intrinsic role of freshwater resources in production systems, but have been described as misleading (Ridoutt et al., 2009), as they fail to consider the environmental impacts of water use. The WF definition by the WFN, therefore, differs from the one used in LCA studies (Ran et al., 2016). Generally, LCA studies on WFs do not include green water, unless changes in the flow of green water are analysed. Furthermore, LCA studies tend to focus on assessing the environmental impacts associated with water use using metrics such a water scarcity and eutrophication potential (ISO, 2014). Efforts have been made in recent years by the LCA community (ISO, 2014) and IDF (IDF, 2010) to work towards a standardised WF method that would overcome the difficulty of WF interpretation and comparability due to differing methods. In this study, green and blue volumetric WFs were included, while grey water was excluded. Furthermore, an LCA mid-point indicator, i.e., the stress-weighted WF, was included to account for the environmental impact of blue water use (Pfister et al., 2009).

The environmental impact of freshwater use in dairying has been addressed in current literature (Palhares and Pezzopane, 2015; Ridoutt et al., 2010; Zonderland-Thomassen and Ledgard, 2012). Variation in results presented by those studies relate mainly to differences in assumptions regarding the composition and amount of feed consumed by animals, the sources and yields of animal feed crops and variability in outputs among production systems. To contribute to better insight into the demand for freshwater in a specific region and to improve the performance of individual farms, there is a need for water consumption studies to include detailed farm level data regarding climate, agricultural practices and utilisation of feed (Jeswani and Azapagic, 2011; Krauβ et al., 2015; Ridoutt and Huang, 2012). The objective of this study was to determine the primary contributors to freshwater consumption up to the farm gate, expressed as a volumetric water footprint (WF) and associated impacts for the production of one kg of fat-and-protein corrected milk (FPCM), on 24 Irish dairy farms.

2. Materials and methods

2.1. System boundaries

Twenty four commercial dairy farms were selected from the Teagasc advisory database, referred to as study farms, which were located in the south and south-east of the country. Selection criteria included availability of herd and production data for 2013 and willingness of the farmer to collect and maintain data accurately. The system boundary was cradle-to-farm gate. Freshwater use quantified included water required for cultivation of crops for concentrate feed, on-farm cultivation of grass or fodder and water required for animal husbandry and farm maintenance, and was expressed per kg FPCM (CVB, 2000). Water use related to energy and fertilizer production was not included owing to its negligible contribution to the WF of milk production in the study by De Boer et al. (2013).

2.2. Data collection

Data on farm infrastructure were collected by means of a monthly survey. This included information relating to on-farm water sources (well/local government supply), types of milk cooling equipment and washing procedures of the milking machine and cow collection area. Water meters were also installed on each farm to record water volumes (m^3) throughout the farm including water used to facilitate milk production processes and water consumed by livestock. Domestic water consumption was measured separately and subtracted from the total water supply to determine water supply to the farm enterprise only. Water volumes were recorded on a monthly basis via an on-line survey with the farmers reading each of the installed meters and inputting the data into the online system. Additional information gathered included farm imports such as concentrate feed and forages. Milk production data were sourced from the Irish Cattle Breeding Federation (ICBF) records. Concentrate fed to dairy cows on the monthly farmer surveys (i.e. opening balance + purchased feed − closing balance) and feed ingredient composition and source information was taken from Upton et al. (2013) which was gathered from local feed mills. Raw data from water meter recording and surveys were exported to spreadsheets and subsequently used to compute the WF of individual farms. Economic allocation was used to allocate water consumption between dairy (91%) and beef production systems (9%) within a farm as this approach has been used for similar livestock systems (De Vries and de Boer, 2010; O'Brien et al., 2014; O'Brien et al., 2012), the more common biophysical approach to allocation (as recommended by the IDF (2010)) was not used but would have yielded similar results.

Table 1 describes the relative share of concentrate ingredients used in this study, country of origin and economic allocation factor for each crop. These data were sourced from Eco-invent (Ecoinvent, 2010) and Feedprint (Vellinga et al., 2013).

2.3. Water required for crop cultivation

Green and blue water consumption required during crop growth was calculated using the method described by (De Boer et al., 2013). Freshwater required to grow a crop can originate from precipitation and soil water (green water) or, in the case where water demand exceeds rainwater availability, from irrigation (blue water). All irrigation water was assumed to be consumptive, implying that irrigation losses did not return to the same water shed, representing a worst-case scenario (De Boer et al., 2013). Water which has been ‘consumed’ refers to loss of water when it is evaporated, incorporated into a product or returned to another catchment.