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Evaluation of water footprint and economic water productivities of dairy products of South Africa

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ABSTRACT

Assessment of water footprint sustainability indicators and economic water productivities is regarded as a cornerstone of the world's sustainability goal and the reduction of the fresh water scarcity risk. These assessments are gaining much prominence because about four billion people face severe water scarcity, globally. Attaining sustainable and economically efficient water use goals requires a thorough assessment of all the existing sectors that use water. This paper examined the water footprint and economic water productivities of dairy products in South Africa for the periods 1996–2005 and 2006–2013 using the water footprint network assessment methodology. We found the total water footprints of all the selected dairy products in South Africa to be higher than the global averages are. During the period of 1996–2005, South African dairy producers utilized more green water in their dairy production. The production of butter and cheese products, whether grated or not grated, powdered or not powdered, blue-veined and cheese of all kinds had the highest total water footprints among all the dairy products in South Africa. Dairy production under a sole grazing system has high water footprints and low economic water productivities, relative to mixed production systems, for the period 2006–2013. With blue water becoming scarcer in South Africa, it is time for dairy livestock producers to shift their production to a system that is highly productive and has low water footprints. The water footprints of most of the dairy products for period 2006–2013 have reduced by varying amounts, relative to 1996–2005, which shows that water users along the dairy industry chains are managing water cautiously. Our findings have revealed dairy products that have high economic water productivities, and suggest that profit maximising and environmentally sustainable dairy producers and water users should integrate both blue water sustainability and economic water productivity indicators in their production decisions.

1. Introduction

In recent years, ecological and environmental sustainability assessments have been gaining much prominence, globally. The global water scarcity phenomenon has become a major issue of distress to governments, policy-makers, water users and water managers as well as private and non-governmental organisations and professional bodies interested in environmental and sustainability issues. It is estimated that about four billion people across the globe face severe water scarcity (Mekonnen and Hoekstra, 2016). An assessment of water sustainability indicators across various sectors of the global economy identified that, the greatest share of the world's freshwater is utilized in food production (IWMI, 2007). About 86% of all the freshwater resources in the world are consumed in food production (IWMI, 2007). This implies that the relative importance of water to food production and human survival cannot be overlooked. As a result of that, researchers and policy makers in recent years are interested in the study of sustainable and economical water utilization in the food sector.

Water footprint assessment is one of the ways of assessing water utilization in the food sector. The water footprint assessment gives an account of the quantity of fresh water utilized in the production of a particular food commodity (Hoekstra et al., 2011). Accounting for green (rainwater), blue (surface and groundwater) and grey (related to assimilating water pollutant) water consumption along the whole product value chain. Sustainability assessment of how water is utilized for food production reveals how producers along the food production chain behave with regards to the blue water available to them; as to whether they are using the available water resources sustainably or not. An important pillar of fresh water allocation is economic water productivity, which quantifies the value obtained by producers per unit of water used in producing a particular product (Hoekstra, 2014). The economic water productivities are calculated after the estimation of

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physical water productivities.

Water footprint sustainability assessments of livestock production systems and products have received some attention in recent years in countries such as Ireland (Murphy et al., 2013), Australia (Ridoutt et al., 2014) and China (Huang et al., 2014). Regarding dairy products, water footprint of assessments of milk and milk products have received much attention in developed countries such as Germany (Drastig et al., 2010), Argentina (Manazza and Iglesias, 2012), New Zealand (Zonderland-Thomassen et al., 2014) and in India (Amarasinghe et al., 2010). Animals and animal products' water footprints across the globe have also been explored based on global averages (Mekonnen and Hoekstra, 2012).

These assessments employed different methods such as the water footprint assessment methodology (Drastig et al., 2010; Mekonnen and Hoekstra, 2012), and life cycle assessment methodology including direct and virtual water consumption (Manazza and Iglesias, 2012; Murphy et al., 2013; Huang et al., 2014; Ridoutt et al., 2014; Zonderland-Thomassen et al., 2014). Most of these studies have focused on developed countries (Drastig et al., 2010; Huang et al., 2014; Murphy et al., 2013; Ridoutt et al., 2014; Zonderland-Thomassen et al., 2014), with little emphasis placed on water-scarce African countries including South Africa. Existing studies that focus on assessing water utilization in the agricultural sector in South Africa are limited to the work of Jordaan and Grové (2012) who assessed the cumulative value added to water along the value chain of small-scale raisin and vegetables in order to determine the point along the value chain where most value is added to water.

Scheepers and Jordaan (2016) recently examined the blue and green water utilization for producing lucerne, used as feed for dairy cows. Owusu-Sekyere et al. (2016) recently quantified water utilization for milk production and processing in South Africa. However, this study focused only on milk with 4% fat and 3.3% protein. At the national level, information on water footprints of some dairy products was available from work of Mekonnen and Hoekstra (2012). However, these studies are limited to the quantification of water footprint indicators only, without accounting for economic water productivities, which is a strong pillar of fresh water allocation.

Nonetheless, some authors have assessed economic water productivities of products in the food sector. For instance, in Tunisia, assessments of some key crops were done to ascertain how productive the country is, in terms of water and land utilization (Chouchane et al., 2015) Schyns and Hoekstra (2014) conducted similar studies for some predominant crops produced in Morocco. Mekonnen and Hoekstra (2014) further assessed water conservation through trade in Kenya. Zoumides et al. (2014) conducted an economic water productivity assessment for crop production in Cyprus. All these studies focused on economic water productivities of crops, but with no similar studies being done on livestock products.

This study aims to assess the water footprint and economic water productivity of primary and derived dairy products for different production systems and periods in South Africa. This contributes to the limited knowledge on economic water productivities in the livestock sector and, to the best of our knowledge, this will be the first step taken towards assessing economic water productivities for dairy products in the dairy industry, particularly in Africa. Findings from this study can potentially assist water and environmental sustainability policy makers to understand whether, how and why consumers, water users and dairy producers along the dairy value chain might shift their consumption and production patterns to more sustainable and economically efficient ones. Insights from this study can further contribute to the current debate on the economic dimension of water footprint assessment.

2. Materials and methods

2.1. The study area

The study was conducted in South Africa. South Africa is one of the driest areas in the world and is ranked 30th in terms of freshwater water scarcity (DWA, 2013). The mean rainfall of the country is about 450 mm (DWA, 2013). According to DAFF (2012), approximately 80% of South Africa's agricultural land is suitable for livestock farming. The main source of water supply in the country is surface water (DWA, 2013). Ground water is widely used in rural and arid areas. A significant volume of water originates from return flows from major urban and industrial developments to streams. South Africa irrigates 1.5% of its total landmass to produce 30% of the total crops produced (DWA, 2013). Backeberg (2005) recounted that irrigated agriculture in South Africa utilizes about 40% of the utilizable runoff whiles agricultural production in general use more than 60% of the available water (DWA, 2013). In the dairy industry sector, large quantities of water are utilized for feed production. About 98% of all the water used along the dairy value chain in South Africa goes into feed production (Owusu-Sekyere et al., 2016).

The South African dairy industry is handled by Milk South Africa (Milk SA) and South African Milk Processors' Organisation (SAMPRO). These bodies consist of dairy farmers, producers and processors, who produce different dairy products for the local and international market. Dairy producers in South Africa do not import composite animal feeds (DAFF, 2015). However, some quantities of feed ingredients such as soya oilcake, yellow maize and fish meal are imported. It must be emphasised that there was no import of fish meal over the past ten years in the dairy industry (DAFF, 2015). There are three main systems of feeding dairy cows. These include: (i) Semi-intensive farm-based ration obtained from available crops, pastures and crop residues with minimal rations purchased. (ii) An intensive, zero-grazing dairy system using a total mixed ration. (iii) A traditional, extensive or dual-purpose system (Milk SA, 2014).

About 56% of dairy cows in South Africa rely on pasture, 38% rely on total mixed ration (TMR) and 6% rely on mixed or dual purpose system (Ercole, 2013; Milk SA, 2014). Table 1 presents production differences between the grazing (pasture) and mixed ration systems of feeding dairy cows for 300 days lactation period. This survey was done as part of a scheme towards dairy cattle improvement in the South African dairy industry. Average milk yield for total mixed ration is higher that grazing system, with a significant mean difference of 1463 kg of milk per cow for 300 days lactation period. In terms of fat content, the survey revealed that the butter fat content per kilogram for the mixed system is significantly higher than that of the grazing system.

Table 1
Mean production differences between grazing and mixed systems of dairy feeding.
Source: Dairy Cattle Improvement Scheme (Milk SA).

System	Milk (kg)	Butter fat (kg)	Protein (kg)	Butter fat (%)	Protein (%)
Mixed	7411 (1489)	310(61)	256(50)	4.26(0.36)	3.48(0.21)
Grazing	5949(1285)	245(50)	203(42)	4.23(0.33)	3.46(0.22)
Mean difference	1463***	65**	53**	0.04	0.02

Values in brackets are standard deviations.
**Indicates significant mean difference at 95% confidence interval.