Livestock Science 187 (2016) 68–79

Contents lists available at ScienceDirect

Livestock Science

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

Review article

Assessing water resource use in livestock production: A review of methods

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A R T I C L E   I N F O

Article history:
Received 14 August 2015
Received in revised form
17 February 2016
Accepted 28 February 2016

Keywords:
Water resource use assessment
Green water
Blue water
Livestock production
Beef production

A B S T R A C T

This paper reviews existing methods for assessing livestock water resource use, recognizing that water plays a vital role in global food supply and that livestock production systems consumes a large amount of the available water resources. A number of methods have contributed to the development of water resources use assessments of livestock production. The methods reviewed in this study were classified into three categories: water productivity assessments, water footprint assessments and life cycle assessments. The water productivity approach has been used to assess benefits derived from consumptive water use in livestock production; the water footprint approach has raised awareness of the large amounts of water required for livestock production; and life cycle assessments highlight the important connection between water resource use and local impacts.

For each of the methods we distinguish strengths and weaknesses in assessing water resource use in livestock production. As a result, we identify three key areas for improvement: 1) both green and blue water resources should be included in assessments, and presented separately to provide informative results; 2) water quality should not be summarized within quantitative assessments of water resource use; and 3) methods for assessing water use in livestock systems must consider the alternative uses, multiple uses and benefits of a certain resource in a specific location.

Contents

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http://dx.doi.org/10.1016/j.livsci.2016.02.012
1871-1413/

1. Introduction

The demand for animal-source foods is expected to double by 2050 (IAASTD, 2008), driven by population growth, urbanization, and rising incomes (Delgado et al., 1999). The major part of the increase in the production and consumption of animal products will take place in developing countries (Alexandratos and Bruinsma, 2012). It will be imperative to limit agricultural expansion into vulnerable ecosystems and avoid irreversible undermining of agro-ecosystem resilience (Naylor, 2009; Rockström et al., 2009b). There is a broad consensus among agricultural scientists that a large part of the expected increase in demand for animal-source food must be met by a sustainable intensification of agriculture, that is, production of more food without using more natural resources, such as land and water, and without increasing emissions into water, air and soil (Herrero et al., 2010; Tilman et al., 2011).

At present, global livestock production demands about 30% of the global agricultural water requirement, including rain and irrigation water used for the production of feed and withdrawals for livestock husbandry (Mekonnen and Hoekstra, 2012). A major part of freshwater withdrawals already take place in basins suffering high water scarcity and the pressure on water resource availability is expected to increase (FAO, 2007; Molden, 2007; Kummu et al., 2014). The number of people living in regions with absolute water scarcity, i.e. with annual renewable freshwater less than 500 m^3 per capita per year (Rijsberman, 2006), is expected to increase from 1.2 billion today to 1.8 billion by 2025. Two-thirds of the world population is projected to be suffering from water stress by 2025 (FAO, 2007; Molden, 2007).

1.1. Water resource use in agriculture

To properly account for different and competing uses of limited water resources it is important to define different types of water use. Two fundamentally different water uses are non-consumptive water use and consumptive water use (CWU). Freshwater withdrawals for domestic and industrial purposes normally have large return flows that, although often degraded as a result of pollution, can in principal be reused downstream. Consumptive water use, most notably evapotranspiration during use, primarily during plant growth of irrigated and rainfed crops and pastures, on the other hand, results in vapor flow leaving the basin that is not available for reuse (Falkenmark and Lannerstad, 2005).

Traditionally, assessments of water use in agriculture have focused on withdrawals from water bodies and aquifers for irrigation, industry, and municipal or domestic uses (e.g. Shiklomanov, 2000). These assessments did not initially account for the agricultural appropriation of huge amounts of naturally infiltrated rainfall in the soil. To illustrate the importance of both soil moisture and water withdrawals for sustainable agricultural production, water resources can be divided into green water, which refers to soil moisture available to plant growth, and blue water, which refers to liquid water stored in water bodies (Falkenmark, 1995). The important role that green water resources play in agricultural production was highlighted at the end of the 1990s (Falkenmark and Lundqvist, 1997; Falkenmark et al., 1998; Rockström, 1999, 1999. Today the concepts of green and blue water are widely used to describe and assess water use in agriculture, including livestock production (e.g. Molden, 2007; Hoekstra and Mekonnen, 2012; Mekonnen and Hoekstra, 2012). Gray water is a third water volume concept that has been introduced to capture the quantities of water being made unavailable for use due to pollution, i.e. the volume of freshwater that is assumed to be required to assimilate the load of pollutants (Hoekstra et al., 2011).

From a hydrological perspective, the distinction between green and blue water is not always ideal, since these two water resources are not always clearly distinguishable from each other. Water flows across the landscape and can change from one resource to the other. However, the distinction between green and blue water is useful for assessing and improving water use since they are managed differently and affect the environment in different ways (Keys et al., 2012). Blue water can be managed in both time and space, for example in reservoirs and through canals and pipes, and is used both for irrigation in agriculture and for domestic and industrial services. Green water, on the other hand, is coupled to land use and primarily supports plant growth on cropland or grassland, and other terrestrial ecosystem services (Schyns et al., 2015).

Green water dominates water use in agricultural production and globally accounts for about 80% of the CWU on agricultural land (e.g. Molden et al., 2007; Rockström et al., 2014). In livestock production, green water accounts for 90% of total CWU (Mekonnen and Hoekstra, 2012), since livestock production also depends on rainfed grazing land. In total about 98% of the total CWU, green and blue, in livestock production can be attributed to evapotranspiration during plant growth, e.g. feed crops, roughage and pastures. Only about 2-–8% of the CWU originates from blue water used as drinking water, for servicing and as feed-mixing water (Steinfeld et al., 2006; Mekonnen and Hoekstra, 2012; de Boer et al., 2013). Estimates of the total global agriculture water footprint indicate that livestock appropriates 29%, with pasture alone accounting for almost 14% of global agricultural green water use (Hoekstra and Mekonnen, 2012; Mekonnen and Hoekstra, 2011, 2012).

Given the levels of blue water scarcity in many regions, future challenges related to water use and water availability in agriculture will be linked to more efficient, but also increased, use of green water resources (Rockström et al., 2009a). This is particularly true for livestock production, which is largely rainfed. Changing dietary preferences for an increasing share of animal source foods (e.g. Delgado et al., 1999; Lal, 2013) underline the need to find pathways to increase water productivity in both crop and livestock production (Molden et al., 2007, 2010). Improved efficiency will be important in this context, but the expected increase in demand for food, and animal-source foods in particular, will require additional water quantities to be appropriated (Falkenmark and Lannerstad 2010; Lannerstad et al., 2014). This development will increase the global competition for the scarce water resources available for agriculture, and result in local environmental impacts such as agricultural horizontal expansion, dwindling rivers and falling ground water levels (Rockström et al., 2007).

1.2. Water resource use in livestock production

In the past decade, a number of papers have proposed different approaches to relating water use in livestock production to local impacts on the environment and ecosystem functions (Milà i Canals et al., 2009; Deutsch et al., 2010; Ridoutt and Pfister, 2010; Ran et al., 2013; Ridoutt and Pfister, 2013). The life cycle assessment (LCA) network developed a water stress-related water footprint (Pfister et al., 2009; Ridoutt and Pfister, 2010, 2013) and expanded the LCA methodology to include water in environmental impact assessments of livestock production (de Boer et al., 2013d). Other studies emphasize impacts of livestock production systems on water-mediated ecosystem functions. One example is assessments of potential changes in water partitioning, like impacts of heavy grazing pressure on vegetation cover and soil composition, influencing water infiltration (e.g. Deutsch et al. 2010).

To grasp the impacts on water use associated with each specific livestock production system, assessments should consider