Journal of Cleaner Production 135 (2016) 9–19

Contents lists available at ScienceDirect

Journal of Cleaner Production

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

Farm water productivity in broiler production: case studies in Brazil

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ARTICLE INFO

Article history:
Received 27 January 2016
Received in revised form
8 June 2016
Accepted 9 June 2016
Available online 13 June 2016

Keywords:
Brazil
Broiler production
Water productivity
AgroHyd farmmodel

ABSTRACT

The expected increase in broiler meat consumption in Brazil in future will lead to further increase in water use. The objective of this study was to quantify water productivity of four Brazilian broiler farms. Water use in the four farming systems was analyzed in terms of feed production, drinking, cleaning, and cooling. One focus was the crop water productivity of the respective corn and soy producing regions in Brazil. After the spatial and temporal boundaries of the farm system and the water flows were defined, the indicator farm water productivity was calculated to assess water use at the farm scale. The farm water productivity describes the ratio of farm output to water input, where the water input is the total of those water inflows into the farm system that can be assigned to the generation of farm output. Farm output is expressed on a mass basis, food energy basis, and monetary basis. The farm water productivity and the crop water productivity were calculated using the modeling software AgroHyd Farmmodel. In all fattening systems, water input for feed production accounted for 99.7% of the total water input. In the four systems, farm water productivity accounted for 0.29–0.33 kg carcass weight per m^3 water input, 2.60–2.88 MJ food energy per m^3 water input, and 0.15–0.17 R$ per m^3 water input. The results showed that the highest water demand was for feed production. Improvements in nutritional management will increase the water efficiency of broiler farms.

1. Introduction

The growing world population and changes in human diets, with the inclusion of more animal products, are expected to cause an increase in low-priced broiler production by 1.9% per year. In 2022 poultry meat will represent 37% of world meat production (OECD, 2013; UNDP, 2006). An increase of 28% in broiler production has been predicted for Brazil by 2020 compared with 2010 (Benning and Chemnitz, 2014). It would be in the interest of the national economy to promote the use of techniques to meet the growing demand for answers to questions regarding the sustainability (with economic, environmental and social dimensions) of agricultural production in food-exporting countries (Ruviaro et al., 2012). Since chicken has a high feed conversion ratio and the water consumption rate is high in broiler farms, it is essential to identify methods to save water and search for sustainable water management methods in order to avoid impending environmental, economic, and social issues in the future (Grocholl, 2011; Leonhardmair, 2013; Pampel, 2011).

Water availability and efficient water use should be considered important productivity factors, since water-related conflicts have been identified in the main Brazilian broiler production regions. Although Brazil has abundant fresh water resources, many of these are located in the north. Therefore, conflicts over water use occur in regions with high population density and industrialization, where water demand exceeds the supply.

In addition, demand for water resources is expected to increase due to climate change. The warmer Brazilian states have a tropical climate with a mean annual temperature varying between 24 °C and 28 °C and mean annual precipitation between 500 and 2200 mm (INMET, 2015). Water supply is becoming an increasing concern for farmers; hence farmers are opting for irrigation and efficient use of available water.

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http://dx.doi.org/10.1016/j.jclepro.2016.06.052
0959-6526/

A closer look at the water assessment studies conducted during the last few years reveals that there are numerous detailed investigations with some significant results for the water used in the livestock sector. Zonderland-Thomassen et al. (2014) analyzed the water scarcity and eutrophication impacts of dairy farming systems in two different regions in New Zealand. Zonderland-Thomassen and Ledgard (2012) calculated differences in water footprint methods. They stated in their study that the use of catchment-specific characterization factors is preferred over characterization factors based on globally spatial data for water footprint studies. Ridoutt et al. (2012) found that meat production does not necessarily impose a heavy burden on freshwater resource availability. Their case study result is likely to be typical of many low-input, non-irrigated grazing systems. Huang et al. (2014) investigated the water demand of milk and milk products produced in Northeast China. The authors found that products can be produced with minimal potential for contributing to freshwater scarcity. Generally, feed production accounts for the main share of water use in livestock and broiler production (Krauss et al., 2015a,b). Given the enormous demand for farmland for animal feed production, production can be increased by either increasing the yield per hectare or enhancing arable land availability, or both, which simultaneously involves an additional increase in water consumption. Drinking water and other technical water for consumption by broilers, barn cooling, and cleaning are also necessary to raise broilers and are important at a farm-scale and sub-basin level (Krauss et al., 2015b). Sub-basin in this context means an area drained by a river. Renault and Wallender (2000) estimated the water productivity (the ratio of output to water input) of broilers, meat protein, and food energy in broilers at 0.244 kg m^{-3}, 33 g m^{-3}, and 1.4 MJ m^{-3} water, respectively. Chapagain and Hoekstra (2003) estimated the virtual water amount in broiler farms, including crop transpiration, soil evaporation, service and drinking water, to vary between 0.9 and 4.2 m^3 water kg^{-1} broiler, while the world average is estimated at 1.5 m^3 kg^{-1}. The wide range in water productivity or virtual water amount is due to the differences in the regions investigated and their climatic conditions, production intensity, and water input. To the best of our knowledge, no case studies with real data on broiler farming are available. Calculation of indicators for farm water use at the farm scale has been underrepresented in case studies to date. However, it is primarily at the farm scale that farmers can be directly addressed and involved. Indicators of water use at the farm scale help farmers to understand the water flow in their farms, to optimize water use by agronomic measures and farm management, and to reduce costs of withdrawal, distribution, and sanitary treatment of water.

This study presents the first farm water productivity calculation in broiler production in Brazil using data from farms located in a region experiencing serious water problems as a result of prolonged drought or climate change supply limits, combined with substantial increases in industrial activity and population. The objective of the present study was to estimate and analyze farm water productivity of broiler production under local Brazilian conditions, as well as to identify the main fractions of water use in broiler production.

2. Material and methods

2.1. General approach

This study considered four farming systems with regard to their respective water consumption for feed production, drinking, cleaning, and cooling. The farm water productivity was calculated according to Prochnow et al. (2012) using the Agrohyd Farmmodel (Drastig et al., 2012). The quantification and assessment of the water flows for assessing the effects of technical innovations and different management options can be done using the Agrohyd Farmmodel. The method of Prochnow et al. (2012) allows calculation of the indicators on a farm scale, which can assist farmers in understanding the water flows on their farms and in optimizing water use by adapting agronomic measures and farm management.

2.2. System boundaries and data

The water productivity of broiler production on the farm was analyzed from cradle to farm-gate. The time frame considered was the farming year 2012. The mean values of the regions for the years 2003–2012 were used for the feed crop yields.

Four farms with common production and keeping systems in the region of São Carlos (Sao Paulo State, Brazil) were investigated. Data on diets, number of animals, fattening duration, feed conversion, final weight, and idle time of the farms were collected using a questionnaire. The questionnaire included farm-basic data (name, contact person, address and location), farm-livestock and output (animal type, animal inventory date, head count, gain of weight per animal, average weight per animal, number of animals slaughtered per year, purchases, losses, and duration of cycle), animal ration (kilogram corn and soy per phase), housing equipment (water demand for drinking, cooling, and cleaning, and size of the barns). To obtain the data of each farm directly, the farms were visited for personal interviews with the responsible persons.

The water demand for feed supply, drinking, and cleaning was taken into consideration. The indirect water demand for the production of N-fertilizer, supply of diesel and electricity, and the construction of farm buildings was not taken into consideration, since this was assumed to be negligible, similar to that for milk production (de Boer et al., 2013; Döring et al., 2013).

Further information on the use of technical water in the barns was collected. Information on drinking water, cleaning water, water for cooling and refreshing was used for this purpose. Two methods were used for cooling the animals. In the first method, 'cooling', cold water is sprinkled from the ceiling onto the broilers at certain intervals, so that it refreshes the air with the cooling effect of evaporating water. The other method, 'refreshing', involves sprinkling of water on the outside of the barn wall to cool the air inside. Five liters per head and cycle were used for cooling, and 2 L per head and cycle for refreshing. Feed for the broilers was not produced on the farms, but was purchased. Data on production conditions such as feed crop yields and crop rotations were obtained from Embrapa (Brazilian Agricultural Research Corporation). For the purchased feed, a questionnaire on feed-component-list (feed name, dry matter fraction, metabolic energy, crude protein, crude fat, crude fiber, feed, year, season, origin region, year, purchases), information on land used for the feed production (year of cultivation), plots (soil types), data on outputs (output of the fields, harvest date, harvest date of the precrop, output water content, and output name) and plants (variety name, acreage, and average yield) was used.

The water demand for feed production outside the farm was considered as indirect water for feed production.

The reference period with regard to crop production for the feedstuffs was the harvest year, starting on the day after harvest of the precrops and ending on the day of the main harvest in the calendar year. The reference period is thus not uniform, but varies from region to region.

Female and male broiler chickens were kept together in the barn. The duration of fattening, live weight at the end of the fattening period, carcass weight, and feed conversion ratio are