Department of Animal Science

WATER USE, CLIMATE CHANGE AND LIVESTOCK

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Tom Tabler, Department of Animal Science, University of Tennessee
Yi Liang, Departments of Biological and Agricultural Engineering/Poultry Science, University of Arkansas
Victoria Ayres, School of Agriculture, Tennessee Tech University
Pramir Maharjan, Department of Agricultural and Environmental Sciences, Tennessee State University
Tanner Thornton, Department of Animal Science, University of Tennessee
Jessica Wells, Department of Poultry Science, Mississippi State University
Jonathan Moon, Department of Poultry Science, Mississippi State University

Climate change, increasing global population, and a change in eating habits towards more animal protein as developing nations become more affluent will likely increase the competition for freshwater resources in the future. Livestock production will be caught up in this competition, driven by the increasing demand for animal products as increasing sectors of the population choose to eat more meat products. Food production takes a large share of the overall use of our natural resources, especially water. The entire amount of freshwater required to generate the goods and services that an individual, corporation or nation consumes is known as the water footprint (WF) of that person, corporation or country (Hoekstra and Chapagain, 2007). Agriculture accounts for **92 percent of the freshwater footprint** of humanity, with the WF of animal production constituting almost one third of the total WF of all agricultural production (Hoekstra and Mekonnen, 2012). Searching for ways to improve water efficiency and productivity in food and livestock systems is critical to tackling future water challenges. Animal products have a particularly large WF per unit of nutritional energy compared to food of plant origin (Gerbens-Leenes et al., 2013). However, the livestock sector is a pillar of the global food system and a contributor to poverty reduction, food security and agricultural development. Livestock contributes **40 percent of the global value of agricultural output** and supports the livelihoods and food and nutrition security of almost 1.3 billion people (Food and Agriculture Organization of the United Nations (FAO), 2023). We must seek opportunities to improve livestock sector practices to make them more sustainable because increasing incomes, changing diets and population growth have led to increased demand and made the livestock sector one of the fastest growing agricultural sub-sectors in low- and middle-income countries.

Water footprint of livestock

Livestock production is the world's largest user of land resources (including water), and engages closely with landscape management, biodiversity, soil conservation and the holistic functioning of agri-ecosystems (Scollan et al., 2010). The major environmental impacts are land degradation, water depletion, pollution, and biodiversity dependent on the system of production and its intensity. Extensive production systems can make positive contributions to landscape and biodiversity, and efficient manure management can improve nutrient supply to soils. Conversely, either through intensive pressure on the land or mismanagement of production systems, livestock can have adverse environmental impacts (Scollan et al., 2010). In addition, water scarcity is becoming an increasing constraint to livestock production.

As many areas of the world display economic development that results in increased purchasing power, a nutrition transition is taking place in which many people are shifting towards more affluent food consumption patterns that include additional animal products (Liu and Savenije, 2008). If, in developing countries, populations continue to increase, especially in combination with economic growth, **demand for animal products is predicted to increase** (Gerbens-Leenes et al., 2013). This will require additional water resources at a time when the world is facing increasing water scarcity, and agriculture is one of the biggest consumers of water on the planet. The WF measures freshwater consumption and pollution along product supply chains (Hoekstra et al., 2011). A distinction is made between blue, green and grey water. Blue water is the amount of surface and ground water required to produce a product. For meat production, this largely refers to irrigation used to produce crops used for livestock feed. Green water refers to rainwater consumed or evaporated. Grey water refers to water required to dilute the wastewater associated with manufacturing/processing to maintain discharge water quality standards. The WF provides a useful number for the volume of freshwater utilized and enables a comparison of water demands of different products or a comparison of water demands for a specific product originating from different locations or production systems.

The WF of livestock will vary depending on the type of animal, the feed consumed and the management practices used in the production process. In general, beef cattle have the largest WF followed by dairy cows, swine and poultry. However, there are additional factors that can affect the WF of livestock, including local climate conditions, soil conditions and water availability as well as the specific production practices used by individual farmers and ranchers. Regarding the WF of various livestock species, Ashish et al. (2023) indicated:

- **Beef cattle** have a large water footprint because they require large amounts of feed and water to grow and reach maturity. Some estimates indicate it can take up to 15,500 liters of water to produce one kilogram of beef.
- **Dairy cows** also have a large water footprint because they require large amounts of water and feed to produce milk. While it can vary widely depending on the cow's diet, the climate, and the type of feed used, the water footprint of one liter of milk can be as high as 1,000 liters of water.
- **Pigs**, because of their smaller size, have a smaller WF than beef cattle or dairy cows, but still need a significant amount of water and feed to grow. It can take up to 6,000 liters of water to produce one kilogram of pork.
- **Poultry** have smaller water footprints than other livestock because of their smaller size and, therefore, require lesser amounts of feed and water. However, it can still take around 3,500 liters of water to produce one kilogram of chicken meat.

The WF of a specific piece of meat is determined by the water use and pollution in each step within the supply chain of the final product. From the perspective of water use and pollution, the most important processes are growing the feed, the drinking water use by the animals, and water for cleaning and processing on the farm and at the processing facility (Gerbens-Leenes et al., 2013), with growing the feed being the major factor. The WF of meat depends on three main factors: 1) **how much the animals eat**, measured as feed conversion efficiency, defined as the amount of feed input to produce a unit of meat output, 2) **what the animals eat**, i.e. the feed composition, and 3) **the feed origin** that determines the WF of the feed, i.e. location where the feed was grown. The WF at a specific location is determined by local climate conditions, such as rainfall and temperature, combined with soil conditions and agricultural practices (Gerbens-Leenes et al., 2013). For poultry, the WF is primarily determined by one factor – the feed conversion efficiency.

The WF of food (meat in particular) could be significantly reduced by changes in consumption patterns, but this would require a major shift in the current global nutrition pattern and a reduction in food wastes, especially in developed western countries. At present, food choices are **driven by increased welfare, with little attention paid to the environment** (FAO, 2012a). The WF of the livestock sector is a major concern going forward, but it is only one of several factors that also include food security, public health concerns, animal welfare and other environmental issues like climate change and greenhouse gas emissions that the livestock industry must address in the coming years if it hopes to remain sustainable and feed an ever-increasing global population.

Livestock production and climate change

Agricultural production is both fundamental to human well-being and a major source of humanity's global environmental impact. The impacts of animal agriculture on climate and water have received much attention (Barton et al., 2020; Pelletier and Tyedmers, 2010). For water, studies have consistently found that more than **98 percent of the WF of meat is attributable to feed** (Gerbens-Leenes et al., 2013). However, there is substantial heterogeneity in environmental conditions and associated environmental impacts among farms at subnational scales (Brauman et al., 2013; Brauman et al., 2016; Poore and Nemecek, 2018). Impacts of water use are particularly heterogenous, as irrigated corn and soybeans used for feed are grown in numerous regions around the world and within the U.S. with very different irrigation demands (Brauman et al., 2013) and facing different levels of water scarcity (Brauman et al., 2016). Producers and consumers of agriculture-based products need to understand how this upstream heterogeneity in water impacts translates through the supply chains in order to make informed management and sustainability decisions about those products (Brauman et al., 2020).

It is well-recognized that the climate is changing globally, and this has major implications for livestock production. Climate and environmental conditions affect livestock growth rates, milk and egg production, reproductive performance, morbidity, mortality and the feed supply. Simultaneously, livestock production is a driver of climate change, generating 14.5 percent of total anthropogenic greenhouse gas (GHG) emissions supply (Cheng et al., 2022). Globally, **livestock occupy about 26 percent of the ice-free land,** typically using land that is unsuitable for cropping (i.e. semi-arid and arid areas) with one-third of the cropland used for feed production (FAO, 2012b). With rising incomes in the developing world, demand for animal products is expected to surge 74 percent for meat, 58 percent for dairy products and 500 percent for eggs (FAO, 2012b). Livestock provide 33 percent of the global protein and 17 percent of the global calories, and livestock production creates substantial employment opportunities for rural

Figure 1. Poultry are susceptible to heat stress when subjected to high temperatures.

Figure 2. Climate change affects livestock and their food supply.

households (Thornton, 2010; Rojas-Downing et al., 2017). The interaction between ongoing climate change and demands for increasing livestock production makes it challenging to increase production while lowering climate impacts and GHG emissions (Cheng et al. 2022).

The thermal environment is the major climatic factor that affects poultry (Figure 1) and livestock (Figure 2) production. Higher temperatures, increasing precipitation variation and more frequent weather extremes alter livestock and associated feed production. Climate change is almost certainly increasing temperatures and, thereby, **increasing heat stress that is known to have negative effects on livestock**. Thornton et al. (2022) estimated global cattle production losses from heat stress by the end of the century would range from $14.89 to $39.94 billion annually. Poultry also are affected by heat stress and show reduced feed intake when subjected to high temperatures, leading to decreased feed conversion efficiency and reduced weight gain. Meat production has been found to be affected by heat stress for all major commercial livestock types (Gonzalez-Rivas et al., 2020). For laying hens, eggshell strength, daily feed intake, egg mass, and egg production are sensitive to heat stress (Mignon-Grasteau et al., 2015). Significant declines in eggshell quality and egg production also are observed in broiler breeders (Oguntunji and Alabi, 2010). The body temperature of poultry is higher and more variable than that of mammals, and they are more sensitive to rising temperatures (Cheng et al., 2022). Chickens can function normally up to an ambient temperature of 27° C or a body temperature of 41° C, but an increase of 4° C in body temperature would be lethal to them (Saeed et al., 2019).

While climate change affects livestock production, the reverse also is true. Livestock production has a substantial effect on GHG emissions, with GHG emissions from livestock estimated at 14.5 percent of total anthropogenic emissions (Cheng et al., 2022). Results from the FAO Global Livestock Environmental Assessment Model (GLEAM) indicate that emissions from livestock supply chains consist of 50 percent methane, 24 percent nitrous oxide, and 26 percent carbon dioxide. Cattle are the major contributor, with about 62 percent of total livestock emissions being split equally between beef and dairy animals. Other species (hogs, poultry, buffaloes and small ruminants) each represent between 7 and 11 percent of the sector's emissions (Cheng et al., 2022). Livestock GHG emissions result from direct effects (raising animals, including enteric fermentation, manure and associated energy consumption) and indirect effects (feed production and related land use change). There is some debate as to which plays the greater role, with some studies indicating that indirect emissions exceed direct emissions, while others indicate the opposite (Steinfeld et al., 2006; Grossi et al., 2019).

Often, more than 90 percent of the water consumption of livestock and poultry production is associated with feed production (Mekonnen and Hoekstra, 2012; Legesse et al., 2017). Information on overall water use should include the amount of blue and green water consumed in the growth process of various crops. Water also is associated with the various inputs necessary to grow the crops (e.g., fertilizers, electricity, fuel, pesticides, etc.) and all the water flows should be accounted for. In addition, many feed ingredients undergo processing prior to consumption. At the processing facility, water may be required as a cooling agent or as an input (e.g., steam use in a feed mill) in feed manufacturing. Furthermore, diet composition differs substantially both across livestock species and within different management systems and different production cycle stages of the same species. Therefore, care is required to accurately determine the relative proportions of the different feed types consumed as well as the geographical location and characteristics of the production systems in which the feeds are grown (FAO, 2019).

Livestock production is a critical part of the overall agricultural economy. Scollan et al. (2010) indicate that the rising global demand for animal products presents several challenges to the meat industry including:

1. The need to continue to deliver productivity (efficiency) gains, particularly in countries predicted to account for much of the future growth of the livestock industry.
2. Improving environmental sustainability.
3. Managing animal and human health risks.

Addressing these aspects will ensure that livestock production continues to play a vital role in global food security and rural livelihoods. Livestock production (particularly intensive production systems) has placed increasing pressures on land, biodiversity, air and water resources (Scollan et al., 2010). As a result, stakeholders across the livestock production industry, the meat supply chain and policy makers to the industry should collaborate on ways to address numerous challenges. It is critical that the livestock production industry work closely with policymakers and others to highlight the multiple roles that livestock play in maintaining the land, biodiversity, food security and livelihoods, particularly of the poor in many developing regions around the world.

Summary

Livestock production is attracting greater public attention because of its impact on water use and climate change. While much of the literature focuses primarily on ruminants, additional research is needed on non-ruminants such as swine and poultry. Water is a limited and precious commodity that must be conserved globally by all sectors of the economy, including agriculture and, thereby, crop and livestock farming. The water footprint of livestock production has **significant environmental, economic and social impacts**. The use of water for livestock production can contribute to water scarcity and pollution, soil degradation, and deforestation, which can lead to long-term environmental damage. In addition, the water footprint of livestock can impact the economic sustainability of farming communities, particularity in areas with limited water resources. In recent years, consumers have become increasingly aware of the impact of their food choices and are more interested in making informed decisions that contribute to a more sustainable future. However, **climate change is affecting livestock**

production and consequently food security, in addition to the nutritional content of livestock products, which are one of the major suppliers of global calories, protein and essential micronutrients. Additional water conservation efforts must focus not only on livestock production, but also on crop production related to the livestock feed supply, which accounts for more than 90 percent of water consumption for livestock and poultry.

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