Department of Animal Science

POULTRY PRODUCTION GOING FORWARD: WHERE WILL THE WATER COME FROM?

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Global human population is expected to reach 9.6 billion by 2050 (U.N., 2013). World water demand is expected to increase by 20-30 percent between 2010 and 2050 (Burek et al., 2016). Demand for agricultural products will increase by about 70 percent as the global standard of living increases during this period (FAO, 2009). Water is a crucial resource for agriculture (FAO, 2019), which accounts for ~70 percent of global freshwater withdrawals (OCED, 2010). Freshwater demands are increasing worldwide, and water scarcity is becoming a threat to the sustainable development of human society (Mekonnen and Hoekstra, 2016). Population growth and climate change are both projected to substantially increase water scarcity for large portions of humanity (Heinke et al., 2019). Increases in water scarcity can affect food production, threatening food security, particularly in developing regions of the world where most of the population is poor (Tong et al, 2016; Huang et al., 2017; Yin et al., 2017; Pastor et al., 2019). Water scarcity in 19 major food crops globally is predicted to increase by 83-84 percent by 2050 (Liu et al., 2022). Driven by increasing global population and rising per capita food demand, global production of animal products has more than tripled over the last 50 years, accompanied by a threefold increase in crops used for animal feed (FAO, 2018). One third of all cropland is now being used to produce feed crops (Steinfeld et al., 2006). Where will the water come from to support this increasing population and rising food demand? Water is a finite natural resource and commodity, and it is critical that we limit further increase in agricultural water demand and seek ways to become more sustainable and produce more agricultural goods per unit of water (Heinke et al., 2020).

Understanding poultry production and water use

Livestock production plays an important role in rural and urban economies worldwide and is a significant source of protein in humans' diets. Between 1960 and 2016, livestock production in the United States increased tremendously, with **chicken and turkey meat production increasing by 10 and 6.3 times**, respectively (Ramos-Tanchez, 2020a). However, growth of the livestock sector can have negative impacts on our natural resources; increased surface and groundwater consumption, water quality deterioration due to manure nutrient losses to surface and groundwater, greenhouse gas emissions and competition for human-edible grains are all possible consequences of food animal production (Ramos-Tanchez, 2020a). In addition, at any given time, some portion of the country faces drought conditions, and, in recent years, large areas of the U.S. have experienced prolonged and extreme drought conditions, with significant impacts on multiple agricultural sectors. Efficient water management is needed to meet the growing demand for food and reduce poverty and hunger throughout the world in a sustainable manner.

Climate change, defined as deviations in patterns of climate over long periods of time, has wide-reaching consequences for agriculture by altering both the yield and nutritional composition of grain crops, many of which are grown as feedstocks for animals used to produce meat. This poses a significant challenge to the poultry industry going forward that relies on large quantities of high-quality feed grains (especially corn and soybeans) to support meat and egg production. Worldwide, around **one-third of total feed grains produced are used for animal feed**; however, with a growing global demand for animal protein due to population and economic growth, this quantity must increase by 38 percent by 2050 (Makkar, 2018). For the poultry industry to meet increasing demands, it is necessary to understand the impact of climate variability and extreme weather events such as drought and increasing global temperatures on grain production, quality and quantity.

Water footprint of food

To comprehend the grand challenge of feeding an ever-increasing global population, it is vital to understand the water footprint (WF) of food. The water footprint concept was developed in the early 2000s and measures the amount of water used to produce each of the goods and services we use (Hoekstra and Hung, 2002). Interest in water use of animal products has grown in recent decades partly in response to consumer concerns about the environmental impacts of food production (Pimentel et al., 1997; Chapagain and Hoekstra, 2003; Hoekstra, 2012; Ridoutt et al., 2012). In the U.S. in 2015, **irrigation accounted for 42 percent** of the nation's freshwater withdrawals (USGS, 2018). Food production requires a lot of water. To understand the water footprint of food, we have to start with the three parts of a water footprint: the blue, green and grey water components. Each part represents the volume of water consumed, evaporated and polluted when an item is produced.

- **Blue water footprint**: The amount of surface and groundwater required (evaporated or used directly) to produce an item — for food this mainly refers to crop irrigation.
- **Green water footprint**: The amount of rainwater required (evaporated or used directly) to make an item — for food this refers to dryland farming where crops and forages receive only rainwater.
- **Grey water footprint**: The amount of freshwater required to dilute the wastewater generated in manufacturing/processing, in order to maintain water quality, as determined by state and local standards.

The water footprint for meat and animal products like milk and eggs is especially high because animal feed typically comes from either irrigated or rain-fed grains (corn and soybeans) or rain-fed forage (grass for ruminants, cattle and, to a lesser extent, sheep and goats), both of which have large blue and green water footprints. Commercial poultry and swine that are typically raised inside and feedlot-raised cattle (which includes the majority of livestock in the U.S.)

consume feed that is primarily composed of corn and soybeans, both of which rely on high amounts of irrigation and rainwater (the blue and green water footprints).

A relatively small share of the water footprint for livestock is composed of water used for drinking, for cooling the animals during summer and for meat processing. However, a much larger share of the water footprint of animal production is the feed they consume. The yearly average of total water consumed by the livestock sector in the U.S. between 2014 and 2016 was 72,650 billion gallons/y (Ramos-Tanchez, 2020b) (Table 1). During the period from 1960 to 2016, water consumption per unit of agricultural good decreased by 36 percent due to an increase in animal productivity (output per head) and the increase in yields of feed crops (Ramos-Tanchez, 2020b). This highlights the importance of optimizing water use in the production of feeds such as corn, soybeans, alfalfa, pasture and other forages, in order to improve the overall sustainability of livestock production. Next to beef cattle, which are responsible for almost half of the water consumption of livestock production in the U.S., dairy, poultry and swine production also have the high water demands (Table 1), most of which occurs in the production of grain or grain byproduct feeds.

Mekonnen et al. (2019) reported that about **99 percent of the WF of livestock production** is related to the feed they consume. Much of the WF of the feed is related to the crop production stage of various feed components including corn and sorghum silage, alfalfa and other forages (30 percent), followed by corn (18 percent), soybean meal (16 percent) and pasture (15 percent). Beef cattle contribute the most (48 percent) to the WF of livestock production in the U.S., followed by dairy cattle (20 percent), broiler chickens (14 percent) and swine (12 percent). A large share of the WF related to poultry production is related to feed grain intake (corn, soybeans, wheat, sorghum and oats), accounting for 52 percent of the WF for poultry products (Mekonnen et al., 2019). These concentrate feed ingredients are largely produced in intensive agriculture settings and require large amounts of nutrients and irrigation water, thus putting pressure on freshwater resources in terms of consumption and pollution. Therefore, much of the effects of drought on the poultry industry are related more to crop production and feed grain quality and quantity than to the animals themselves. However, drought is often accompanied by high environmental temperatures that can have direct heat stress effects on livestock. Because the water demands for crop production could be utilized for other purposes, animals such as poultry that are fed grain-based diets could be considered in competition with domestic and industrial uses of humans for available freshwater resources.

Table 1. Total annual consumptive water footprint of animal production in the U.S. (billion gal/yr) for the period 2014-2016[1]

Animal category	Grains	Oilseed meals	Other byproducts	Forage	Pasture	Drinking/service water	Total
Broilers	5,155	4,423	260	-	-	96	9,934
Layers	1,438	1,233	73	-	-	13	2,757
Turkeys	993	851	50	-	-	3	1,897
Swine	5,417	2,378	274	-	-	495	8,564
Beef cattle	2,987	2,252	3,898	17,038	8,225	245	34,645

Dairy cattle	1,038	3,851	3,092	4,441	2,317	79	14,819
Total	17,028	14,988	7,648	21,479	10,542	930	72,615

[1]Adapted from Ramos-Tanchez, 2020b.

Impacts of climate change on poultry production

For the poultry industry and poultry production in the future, this poses a challenging question. **Where will the water come from?** Climate change is a serious threat to agricultural development. It affects livestock production through competition for natural resources (particularly water), quantity and quality of feeds and forage, heat stress, livestock diseases and pests, and biodiversity loss at a time when demand for livestock products worldwide is increasing dramatically. In addition, climate change threatens a delicate balance between productivity, food security and environmental preservation. While climate change will impact the poultry sector throughout the food supply chain — from production at the farm level to processing operations, storage, transport, retailing and marketing, and human consumption — uncertainties remain as to the magnitude of these impacts (Godde et al., 2021). Factors to consider for poultry production include:

- Flock heat stress associated with climate change is a severe challenge to poultry farmers because of its negative effect on chicken welfare, productivity and livability. Are current cool cell systems adequate, or is there something more sustainable from a water use standpoint?
- Poultry farmers must deal with changes in rainfall amounts and patterns, heat waves, droughts and variability in other climatic elements (humidity, CO_2 levels, etc.).
- Heat stress on poultry reduces feed intake, weight gain, carcass weight and protein/muscle calorie content.
- Heat stress on hens reduces reproductive efficiency and, consequently, egg production.
- Egg weight and shell thickness may also be negatively impacted by increasing environmental temperatures.
- Water availability becomes a serious concern. Water is used not only for drinking but also to cool birds using sprinklers or evaporative cooling systems. Most poultry farms water their birds from wells to avoid the high cost of purchased water. However, **drought conditions that threaten many aquifers**, and wells going dry are an all-too-common occurrence on many poultry farms during periods of high environmental temperatures and low rainfall.
    - Evaporative cooling systems, while beneficial at lowering inside poultry house temperatures during extreme conditions, create high humidity levels inside the poultry house and have come under question recently from a sustainability standpoint for their use of massive amounts of water.
    - Sprinkler systems that use less than half the amount of water for cooling than what an evaporative cooling system uses may be a more sustainable and environmentally friendly option from a water conservation/sustainability point of view.

- Most commercial poultry farms are required to have at least two water supplies. Many growers drill wells as their main water supply and use rural or community water supplies as their backup system. However, even two supplies are not a guarantee of a continual water supply for poultry because wells may go dry during periods of drought or extreme heat and rural or community supplies may be rationed or cut off entirely to poultry farms to adequately supply the human population water needs during drought conditions.

Direct impacts

- Drought, heat and climate change can impact poultry production by stressing the bird's ability to maintain homeostasis. Poultry can adapt to a hot environment only to a certain extent. However, in extreme climatic conditions (high temperature/humidity, water scarcity, etc.), birds must expend energy to regulate their body temperature and, therefore, divert nutrients that could otherwise be used for production.
- Production losses (reduced growth rate, lower egg production, increased disease threat and higher mortality) result from stressful environments or diversion of nutrients.
- Increasing temperature is **likely the greatest climate change factor** directly affecting poultry.
- Changes in humidity may compound effects of high environmental temperatures. Birds reduce their feed intake in a hot environment to limit metabolic heat production. High humidity makes it increasingly difficult for birds to cool themselves and evaporate water off their respiratory systems.
- Laying hens respond to increasing temperatures by reducing the number and the size of eggs produced. Stressful weather conditions negatively affect internal and external quality of eggs; thin eggshells that crack during egg processing.
- High temperatures that often accompany drought conditions result in lower fertility rates, egg hatchability and chick quality.
- Heat-stressed males produce semen with lower sperm quality and concentration.
- In most cases, the **major impact of heat stress is reduced productivity and animal welfare**. However, mortalities will occur under severe or prolonged conditions. Reduced feed intake is often the first and foremost consequence of heat stress, resulting in declines in growth rates and production of eggs.
- Commercial producers and smaller backyard flock keepers face many of the same challenges. However, small flock and pastured poultry producers must also deal with the fact that, during a drought, there are fewer insects and grass for chickens to eat, increasing the risks of overgrazing, nutrient load on the pastures and impact on groundwater resources, particularly in areas of karst topography.

Indirect impacts

- Poultry feed and water intake are closely related. If water availability is limited due to drought/climate change, thereby restricting poultry water intake, feed intake and growth rate will also be reduced. We currently see this in dry regions such as Sub-Saharan Africa, where climate change is resulting in reduced water in ponds, rivers and streams immediately after the rainy season because of an increased rate of evaporation.

- As a result, arid and semi-arid regions experiencing increasing temperatures, low rainfall and irregular rainfall patterns cannot produce the bountiful harvests needed to avoid grain shortages and rising feed prices.
- While decreased crop productivity and increased market prices may create hardships for modern nations, these same impacts **create malnutrition and become life-threatening events in areas such as Sub-Saharan Africa and other developing regions** of the world struggling to feed themselves.
- Temperature increases and precipitation shifts may accelerate the development of certain livestock pathogens and parasites, in conjunction with distribution of their vectors, exposing livestock to novel pathogens.
- Heat stress also weakens immune function in livestock. In combination, these factors could create the need for an increase in veterinary medications at a time when the poultry industry is focused on reducing and removing antibiotic use in poultry production.

Management practices

- We must recognize the need to improve the productivity and environmental performance of the livestock sector (including poultry) in order to minimize its environmental impacts and increase the sustainability of global food production.
- Improvements in livestock productivity, feed efficiency and crop yields, as well as the wise use of feed options, can help reduce the sector's demand for resources such as land and water and its environmental impacts.
- Better animal management to reduce water requirements at livestock facilities, increased use of crop residues and crop byproducts for feeds and forage, and the substitution of alternative feed crops that have smaller water footprints are opportunities to identify and implement methods to further reduce the livestock industry's water use.
- Reducing food waste could also dramatically reduce the environmental impacts of the livestock sector. Approximately **one-third by weight of food produced globally for human consumption was lost or wasted** in 2009 (FAO, 2011). Approximately three-quarters of the WF of food loss and waste is related to cereal grains, fruits and vegetables.
- Poultry growers can take action at the farm level to conserve water throughout the year. Managing drinker line height and regulator pressure to match the age of the flock is critical to prevent water wastage and wet litter. Wet litter is detrimental to the poultry house environmental and a serious animal welfare concern.
- Cool cell systems are capable of moderating house environments during periods of high temperatures but **use huge amounts of water** to do so. In addition, they increase the humidity inside the house making it more difficult for the birds to cool themselves through evaporative respiration. The increased humidity levels for prolonged periods may also lead to an **increase in wet litter and a decline in animal welfare**.
- Sprinkler systems that focus on cooling individual chickens and not the environment that the birds live in use **approximately half the water that cool cell systems use** and are likely a more sustainable cooling option in the future.
- Research is currently underway to **identify strains of birds that perform well using less water intake** than current strains.

- Water meters on drinking and cooling water lines are valuable tools to track water use and assist farmers in better understanding where their water usage goes.

Neither crops nor livestock survive without a constant and sustainable water supply. How well the poultry industry manages that sustainable water supply will determine its production success going forward. This will require futuristic thinking because the issues of water scarcity and climate change are **more challenging and complex than anything we have faced** in the past. Whether or not we can feed a global population of approximately 10 billion people by 2050 depends, in large part, on how well we address the water scarcity issue going forward. Because without water, little else will matter.

Summary

Water scarcity can affect food production, threatening global food security (particularly to those in developing regions of the world). Climate change is projected to have negative impacts on water availability in the future and thus threaten food production in many areas around the world. Poultry production depends on an available and sustainable water supply not only for direct livestock-associated needs (drinking, cooling, meat processing, etc.), but also indirectly for the huge amounts of feedstocks (grain crops such as corn, soybeans and others) grown as livestock feeds. The water footprint for meat and animal products is high because animal feed typically comes from either irrigated or rain-fed grains or rain-fed forage, both of which have large blue (lakes, streams) and green water (rainfall) footprints. For the poultry industry, climate change challenges the maintaining of a balance between livestock productivity, food security, and environmental preservation. The **poultry industry is not immune to climate change** that is resulting in more frequent and severe droughts and floods, increased heat stress on feedstocks and livestock, and rising global temperatures that are placing increased demands on a highly integrated global food production system and a quite fragile supply chain system. The industry must develop a plan to adapt to current and future challenges facing crop and livestock production and to a very real agricultural water scarcity issue, realizing that adaptation of any intervention is subject to localized conditions, socioeconomic factors, and the feasibility of the intervention(s). Any intervention that costs too much or takes too long to demonstrate benefits likely will not be adopted despite its future potential. Accurate targeting of interventions (feed grain production opportunities and enhancements, water conservation/sustainability practices, genetic adaptations in poultry breeding stock, etc.) will be key to addressing the “Where will the water come from?” question challenging the poultry industry today and into the future.

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