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Water footprint and nutrient efficiency in swine and poultry

Julio Cesar Pascale Palhares
Embrapa Southeast Livestock - Brazil
julio.palhares@embrapa.br

Abstract
Water and its use is an essential resource for food security and access to safe and reliable sources and is the basis of global food production. We should promote animal systems that improve nutrient and water efficiency, and are resource-conserving. In this way, we will improve the resilience and adaptability of these systems. The amount of water that is used in animal agriculture influences society's view of its environmental sustainability. The water challenges can no longer be solved within the livestock sector alone because the driving forces and the solutions often lie outside the livestock sector itself. Science and technology are necessary but not sufficient to understand animal systems changes. Other political economic, cultural, and ethical factors are also important. Increases in water and nutrient efficiency and productivity will be achieved internalizing the livestock water management: defined as the daily use of knowledge, practices and technologies that guarantee the supply of water in quantity and quality. Knowledge about relationship between swine and poultry nutrition, water consumption and waste production is essential for economic activities that have been questioned for their sustainability. The establishment of indicators that express these relationships will assist decision-making by actors in the production chain, and provide social evaluation of these activities.

Keywords: holistic, impact assessment, nitrogen, phosphorus

Introduction

Domestic markets in developing countries are increasing their consumption of animal protein, and in this scenario Brazil will have social and economic benefits. The question that arises is: can Brazilian animal agriculture grow but preserve and conserve the environmental quality? It adds another question: what is the environmental condition of the Brazilian animal agriculture? Apart from a few studies addressing this issue, information is punctual and often outdated. It is essential to know the environmental condition in order to plan and act. If you do not know, when questioned by consumers, customers, and markets, there are no answers to give and the risk of losing the social and economic benefits will be high.

One of the paradigms that must be replaced immediately is the productivist. In this paradigm the professionals/researchers understand points, but do not relate the points with each other, with environmental resources, and with other sciences. An example of this approach is the thought that the only environmental problem in animal agriculture is their waste. It leads to interventions in waste management, without considering that wastes are a consequence of the productive system. This kind of approach does not provide long-term solutions, is highly dependent on technology, and has high cost. This approach prevents the desired equilibrium between environmental, social, and economic dimensions.

We need to internalize the systemic paradigm, where interventions will not be in the activity or management, but in the system. This approach requires professionals/researchers with multiple skills and with the ability to relate and analyze them in order to propose interventions that consider all factors of the system. An example of this approach is considering animal nutrition as a tool for environmental management. The precise nutrition will produce a lower quantity of waste and generate less excretion of nutrients. The cost of nutritional management should be related with the cost to store, treat, and use the waste as fertilizer. Unfortunately, professionals and researchers that consider this paradigm are still rare.

Knowledge about relationship between swine and poultry nutrition, water consumption and waste production is essential for economic activities that have been questioned for their sustainability. The establishment of indicators that express these relationships will assist decision-making by actors in the production chain, and provide social evaluation of these activities.

Water Footprint

Simple questions, but still difficult to be answered are: how much water an animal consume? How much water is consumed to produce one kilogram of meat or milk? These answers need to be given to the society and managers of water sources. In this way, animal production chains have a less confrontational and could demonstrate, that despite being a water intensive activity, have practices and programs aimed to improving water efficiency. Studies aiming to answer these questions began to be made in recent years. There are several methods that can be used to it. One method has had greater acceptance by the scientific community, governments, and media is the water footprint approach.

Berger and Finkbeiner (2012) conclude that we have been neglected for many years due to a lack of both awareness and appropriate methods for accounting and assessing water use and consumption, water footprinting is now a priority in current sustainability discussions. ASAS (2014) understanding how animals utilize water in different management systems is necessary to standardize methods to quantify this utilization and improve the sustainability of meat, dairy, and poultry products to meet the growing global demand for animal protein. Ridoutt and Pfister (2010) water footprint has become part of the local vernacular in many countries and reproduced widely in the popular media. The approach making transparent the relationship between the production and consumption of products and the unsustainable use of freshwater resources, and also a capacity will be created for change through public policy and through corporate and individual action. Kounina et al. (2013) the evaluation of freshwater use is possible by assembling methods in a comprehensive methodology to adequately characterize each use. The current state of the art can already provide a preliminary understanding of water uses and associated impacts. Manzardo et al. (2014) underlined the importance of applying water footprint accounting to minimize local effects on water resources, such as water stress and availability.

The water footprint approach provides information about water consumed and the impact of the product in the quantity and quality of water. Several approaches exist for assessing water footprint, and one of them is the Water Footprint Network method (Hoekstra et al., 2011). The water footprint concept was introduced as an indicator of freshwater appropriation, with the aim to quantify and map indirect water use and show the relevance of involving consumers and producers along supply chains in water resource management (Hoekstra et al, 2011). The footprint can be diverted into the three components: the "blue" water footprint, as water used for irrigation withdrawn from rivers, lakes and aquifers, the "green" water footprint, as water used stemming from precipitation and soil water, and the gray water footprint as volume of used and thereby polluted water for each component of a supply chain.

In 2009, when the global average water footprint of animal products began to be released in Brazil this caused a series of questions by production livestock chains and society about the relationship between water and animal agriculture. Due to this fact, the Brazilian livestock sector has established a strong resistance to the term "water footprint" and any discussion involving its calculation.

Society and the productive sector did not have knowledge about methodology and its premises, how to interpret the results and how to use them in decision making, so the conflicts were intense. In that moment the lesson was, regardless of the method used to calculate the water footprint and its premises, we should have a strategy of reporting the results, explaining the production system of reference, geographic area, and time series, only in this way, the results would have potential to use in the decision making and the value of the water footprint could be internalized by all actors and used to improve the water efficiency in livestock production.

To interpret the water footprint and relate this with the increase of livestock water efficiency and productivity it is necessary to understand and manage water in its three dimensions in a farm production system: feed, input and natural resource. Water is one of the most important feed, because it is a source of nutrients, so it should be cared for, managed and offered according to the strictest standards. The performance and welfare of the animals depend on this feed is offered in quantity and with quality. Water is an input when we use it to wash a facility or equipments, cool the animals or remove wastes. In the condition of natural resource the water must be conserved in order to provide the resilience of the productive system. Figure 1 explain how these three dimensions are related with green and blue waters and impact assessments.

Increases in water efficiency and productivity will be achieved internalizing the *livestock water management: defined as the daily use of knowledge, practices and technologies that guarantee the supply of water in quantity and quality*. Variation in livestock water use can mainly be explained by differences in feed quality, digestibility, and feed conversion efficiency. It is fundamental update knowledge and promotes the capacity building of farmers and professionals. Figure 2 shows farming measures that have positive impacts in water efficiency and productivity and their social and economic aspects.

Currently, the limitations for calculating the water footprint for Brazilian animal agriculture are: lack of a water culture and water management in farms and production chains; lack of information for calculate, it increases the necessity of inferences and uncertainties and conflicts; low interaction between agriculture and livestock; livestock production is a source of point and diffuse pollution, so it is necessary to measure these two sources to improve the calculation; absence of holistic vision in actors chains and decision makers; aversion of some actors in the water footprint methodology, therefore, low cooperation for work together; low understanding of the methodology by actors and society; sensationalism of the media in spreading the water footprint values.

It is understood that knowledge of the water demand of the various animal production systems is an opportunity to: provide water use data, it is the main barrier to calculate the water footprint because we do not have information about the use of this resource by animals and Brazilian production systems; ensuring availability of in water quantity and quality; internalize the water in its three dimensions to animal agriculture; know the water consumption of green, blue and gray by the various systems in different regions and conditions in order to facilitate the management of this resource, promoting the efficiency of water use and establishing best water practices; reduce conflict between production chains and society; detect vulnerable areas; formulate policies and set goals for reducing water demand (increased water efficiency); assist in formulating zoning and water management programs; know the flows of virtual water.

Water footprint of pigs slaughtered in the central-southern states of Brazil

The relation between water and pig production is an issue that must be addressed immediately and in a systemic approach, because pig production is a constant threat to quantity and quality of water sources. The study considered the number of pigs slaughtered in Brazil in 2008, according data from Brazilian Geography and Statistics Institute (Palhares, 2011). The choice to evaluate the States located in the Central South is justified because these concentrate 98.3% of slaughter in the period. We used the methodology proposed by Chapagain & Hoekstra (2003) that consider the water consumed in the grain production (corn and soybean), drinking and cleaning waters (Table 1).

Water consumption to produce one ton of corn in the study region is 4,500 m^3 ha^{-1}. The index used to calculate water consumption to produce one ton of soybean was 6,000 m^3 ha^{-1}. Using the mean productivities for the crops in each State, according data from National Supply Company, we calculated the amount of water consumed to produce corn and soybean. In soybean production we have three products: grain, soybean meal and oil. Soybean meal is the product consumed by pigs. Therefore, not all water consumed in the production can be counted in water footprint. Using index listed in the Agricultural Commodities Conversion Factors (FAO, 1996), we considered that 77% of production is soybean meal and 23% is oil.

Table 2 shows water footprint of pigs slaughtered by State in 2008. Table 3 the percentage that corn, soybean meal, drinking and cleaning waters represent in the footprint. The State with the largest water footprint was Rio Grande do Sul (2,702 km^3), followed by Santa Catarina (2,401 km^3) and Parana (1,089 km^3). These States concentrated 70.3% of slaughters in 2008. States with the lowest footprint were Rio de Janeiro (0.00215 km^3), Distrito Federal (0.0354 km^3) and Espirito Santo (0.0719 km^3). These accounted by 1.1% of the total slaughters in 2008. Although Rio de Janeiro and Espirito Santo presented the worst productivities to corn and soybean, this didn't reflect in a large footprint due the low number of slaughters. Distrito Federal had the best productivity to soybean and the second to corn, but as it represented only 0.5% Brazilian slaughters, these high productivities didn't impact the value of footprint.

National mean of water consumption by crops in the footprints calculation was 99.88%. Crops with lower productivities promote high footprints. This demonstrates the importance of improving crops productivities that are basic in pig diets.

The calculations performed in this study showed that the improvement of water productivity in pig production depends on the improvement of corn and soybean productivities. It does not delete actions, programs and policies to reduce the consumption of drinking and cleaning waters in farms. Pig production is highly concentrated in the Brazilian South region, so the consumption to drinking and cleaning will always be a threat to water security in this region. The majority of water consumption to produce pigs is in the crops rather than consumption for drinking and cleaning. This inserts a change of vision; the water management of pig production can not only happen inside the farm, but it should cover the production chain. Zoning becomes an important factor in order to regulate the expansion of crops and swine in the territory, as well as subsidizes communities, government and Watershed Committees in decision-making. This new vision must also consider water consumed in slaughter and products. The difficulty in calculate these intakes is the lack of information to Brazilian reality.

Influence of nutritional technology on water and performance indicators of pig production

Water is the nutrient required by pigs in greatest amount. Its consumption is influenced by several factors but type of diet is by far the most important. Therefore, a well formulated diet will demand less water consumption and hence promote rational use of water sources. This diet will also provide environmental and economic benefits, because it will generate less waste, reducing environmental risks to surface and ground water, soil and air. It will also reduce management and treatment costs. Dourmad and Jondreville (2007) there are several nutritional technologies that reduce chemical output by animals. Increasing Nitrogen, Phosphorus and micro mineral utilization by pigs improves environment quality, by reducing local nutrient importation from other regions and better use of non renewable natural sources.

Usually, environmental costs are not taken in account in swine production. This cannot be accepted for an activity that is routinely questioned about its environmental performance. Therefore, a diet planned to consider environmental technologies in its formulation, may have higher cost but have a positive impact on reducing the environmental hazards. Consequently, they reduce environmental management costs.

The objective of this study was to propose water and performance indicators to growing-finishing pigs, and evaluating the effect of nutritional technologies on indicators.

The experiment was conducted in a swine production facility during 17 weeks (119 days). Eighty barrows, Landrace x Large White crossbred with MS60 syntetic boars, with average initial weight of 30 kg average age of 77 days were allotted in a randomized block design. The experiment was divided in four phases: 30 to 50, 50 to 70, 70 to 100 and 100 to 130 kg. The experimental unit (replicate) consisted of a pen with four animals.

The treatments were:

T1 - Diet with high level of crude protein, minimum amino acid supplementation, and without the inclusion of phytase and organic minerals;

T2 - Diet based on T1, with reduced level of crude protein by supplementation of lysine, methionine, threonine and tryptophan, with ideal protein of all essential amino acids, and without the inclusion of phytase and organic minerals;

T3 - Diet based on T1, with the inclusion of phytase and reduction of Calcium and Phosphorus;

T4 - Diet based on T1, with the supplementation of microminerals (Cu, Zn and Mn) on the basis of 44% organic and 56% inorganic minerals;

T5 - Diet based on T1, but combining all supplemantations of T2, T3 and T4.

All diets were isocaloric and formulated based on digestible amino acids using the concept of ideal protein. Basic ingredients were corn, soybean meal and oil, without the inclusion of animal by-products. Brazilian Poultry and Pigs Requirements (Rostagno et al., 2005) were the reference for nutritional requirements of animals to formulate diets. In the diets of Treatments 4 and 5 the contents of copper, zinc and manganese were supplemented with inorganic and organic minerals at a rate of 56% and 44%, representing the reduction of 10% in the total amount of supplemented minerals compared to T1. Diets were mashed type and phytase was added following commercial recommendations regarding reduction in supplemented Phosphorus and Calcium.

Each pen had one 50 L water tank placed above the animals. Daily, the volume of the tank was refilled. Therefore, the difference between gallon capacity and the volume refilled indicated the water intake into the pen. The tank was connected to a drinker designed to reduce losses as much as possible. Before and after the daily replacement, water temperature was measured using a thermometer with mercury bulb. Weekly, total waste produced was collected in each pen. After collection, the manure was weighed. The division of the total waste by the number of pigs in each pen generated the result of kg of waste produced per animal.

The chosen indicators to measure performance, waste production and water use were: IND1 - water consumption and waste production (L kg^{-1}); IND2 - water consumption and weight gain (L kg^{-1}); Ind3 - water consumption and feed consumption (L kg^{-1}). Variables were analyzed using various procedures of SAS (2002) and the general model included main effects of blocks and treatments. Univariate and multivariate analysis techniques were employed.

Considering that ideal temperature to drinking is 20^0C, it was observed that the mean value was slightly above the ideal, but there was no statistically significant difference between the water temperature before and after replacement among treatments.

Figures 3, 4, and 5 show IND1, IND2, and IND3. Treatment 5 had the highest ratio between water consumption and waste production (2.72) while Treatments T2 (2.22) and T3 (2.25) had the lowest ratio. It was expected that the largest ratio occurred in T1 because this diet had any of the chosen nutritional technologies. The largest ratios occurred in treatments containing organic minerals. Higher ratios has a direct impact on the environmental cost of pig production, because volume is one of the main parameters used in the design of storage and waste treatment systems. T2 and T3 had a positive effect in reducing the need for labor to cleaning pens, cost of environmental management, reducing the potential pollution, especially that related to surface and groundwater; need for agricultural area when the use of manure as fertilizer.

The ratio between water consumption and weight gain increased with the age. In the first week the average of treatments was 3.7 L $kg^{-1}$and in the last week was 6.3 L kg^{-1}. This increase is related to animal physiology, since older animals are less efficient to convert nutrients in meat. Water is the main nutrient in a livestock. If it is used with lower efficiency it decreases water availability to farms and environment. Therefore, the decision on the best slaughtering weight cannot be limited only by market needs, but also consider the environmental impacts that this decision could have. The actual trend is to increase animal concentration in farms and regions, slaughtering animals at heavier weights, which will demand higher water availability.

The lowest average water intake was observed in T5 (5.0 L kg^{-1}) and the highest in T1 (6.0 L kg^{-1}). The difference of 1 L/kg between these treatments is significant when we consider the difference during experimental period. The animals were housed with an average weight of 30 kg and slaughtered at an average weight of 130 kg, weight gain during the period was 100 kg. Multiplying this value by the difference between T5 and T1, each animal under T1 drank 100 liters more than the ones in T5. If we project this difference to an industrial farm the impact will be huge to conservation of water sources.

Treatments with organic minerals had the lowest ratio between water consumption and weight gain, showing that this technology can be used when farmers aim improving water efficiency.

The ratio between water consumption and weight gain can be used as an indicator of environmental performance and water efficiency. Therefore, it is necessary that the practice of measuring water consumption be internalized in the daily of farm.

Traditionally, farmers and profissionals use the ratio of 2 to 3 L of water per kilogram of feed. The results showed that treatments did not differ significantly and that the average ratio ranged from 2.13 L kg^{-1} (T1) to 1.74 L kg^{-1} (T5). The use of all technologies on the same diet provided a lower consumption of water per kilogram of feed. Despite the low difference between the maximum and minimum average (390 ml), when we project this difference to the current scale of production, the difference will be significant.

Animal nutrition should be understood as an important factor on the generation of production wastes. Therefore, any practice or technologies that improve the utilization of nutrients should be evaluated in theirs productive, economic and environmental factors. Today, the economical evaluation is the main criteria to take decisions in swine production, which can lead to important environmental liabilities.

Water use efficiency and farm water productivity in broiler production

Palhares (2012) calculated the water footprint of broiler slaughtered in the decade 2000-2010 in each Brazil South-Central. Calculation considered indirect water, consumed in grain production, and direct water, consumed at the farm. Table 4 shows the water efficiency by year to each State. South States had the highest footprints and the largest number of slaughterings during the period. The average footprint for Parana in the decade was 4.334 km^3 (99.7 green and 0.3 blue) and Rio Grande do Sul 4.216 km^3 (99.8 green and 0.2 blue). The difference in water footprint average was 0.027%, although the difference between the number of slaughterings have been 7.1% on average. Between years, 2005 had the highest and 2001 the smallest footprints. Slaughterings remained growing and/or constant in all states. Annual variation was determined by productivity of corn and soybeans.

Drastig et al. (2016) estimated and analyzed farm water productivity of broiler production under local Brazilian conditions and identified the main fractions of water use in broiler production. The 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). The water productivity of broiler production in the farm was analyzed from the 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 Sao 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.

Results showed that hydro-efficiency depends on agriculture and the use of the best management practices to produce feeds, because the biggest water demand to produce meat is in feed production. Therefore, one approach for improving water productivity of broiler will be within the feed production of the supply chain. The results indicate that feed production accounts for the major share of water input in the four broiler farms investigated. Therefore, improvements are called for in production and feed efficiencies, crop yields and management strategies, resulting in reduced water requirements and improving water productivity and environmental performance of broilers.

Environmental challenges to Brazilian Livestock

The challenges listed are inherent to all animal activities. They will be met in the short, medium, and long term due to the specificities of each animal agriculture activity, region, structure of Environmental State Agencies, social pressure, and environmental values of Brazilian society. Another fact that must be considered is that Brazil has deep environmental, social, cultural, and economic contrasts.

Resources and Inputs Use Efficiency

- Internalize managements to reduce the consumption of renewable and non-renewable resources and establish indicators for the assessment of this consumption;
- Improvement in the efficiency use of resources and inputs (water, energy, and nutrients), and to re-use them and reduce their losses;
- The nutrient fluxes in the various production systems must be known in order to improve efficiency (amount of resource/input per kilogram or liter of product). Special attention should be given to the flows of nitrogen and phosphorus because of its nutritional, economical, and environmental importance;
- Work with more environmentally friendly ration formulations. It results in less nutrient being excreted, so the cost of environmental management will be decreased;
- Use nutritional precision technologies to improve the use of nutrients and reduce the nutrient wastages;
- Use treatment technologies to promote the re-use of resources and nutrients.

Environmental Impact Assessment

- Utilize methodologies such as: nutrient, material, and energy balance, life-cycle assessment, and footprints (ecological, water, and carbon) to assess the impact and environmental performance;
- Establishment and monitoring of indicators to evaluate environmental performance;
- Know the soil capacity for the use of wastes as fertilizer and have as a reference element the nitrogen,

and—for environmentally sensitive areas—phosphorus;
- The farm should have a minimum percentage of agricultural area, and choose plants that have high capacity for nutrient uptake;
- Use management systems to reduce the amount of residual phosphorus in the soil;
- The maximum permitted application of manure could be stipulated below the economic optimum value;
- Use treatment technologies to reduce nitrogen and phosphorus concentrations in the wastes and effluents;
- Identify the impact of livestock for the presence of pathogens, metals, hormones, and antibiotics on environmental and human health, and propose actions to reduce it;
- Know the contribution of production systems to the local and regional landscape and assist in maintaining the ecological structure;
- Develop constructive and equipment technologies that reduce the consumption of resources/inputs and nutrient wastages, promote their efficient use, and improve the health of the worker.

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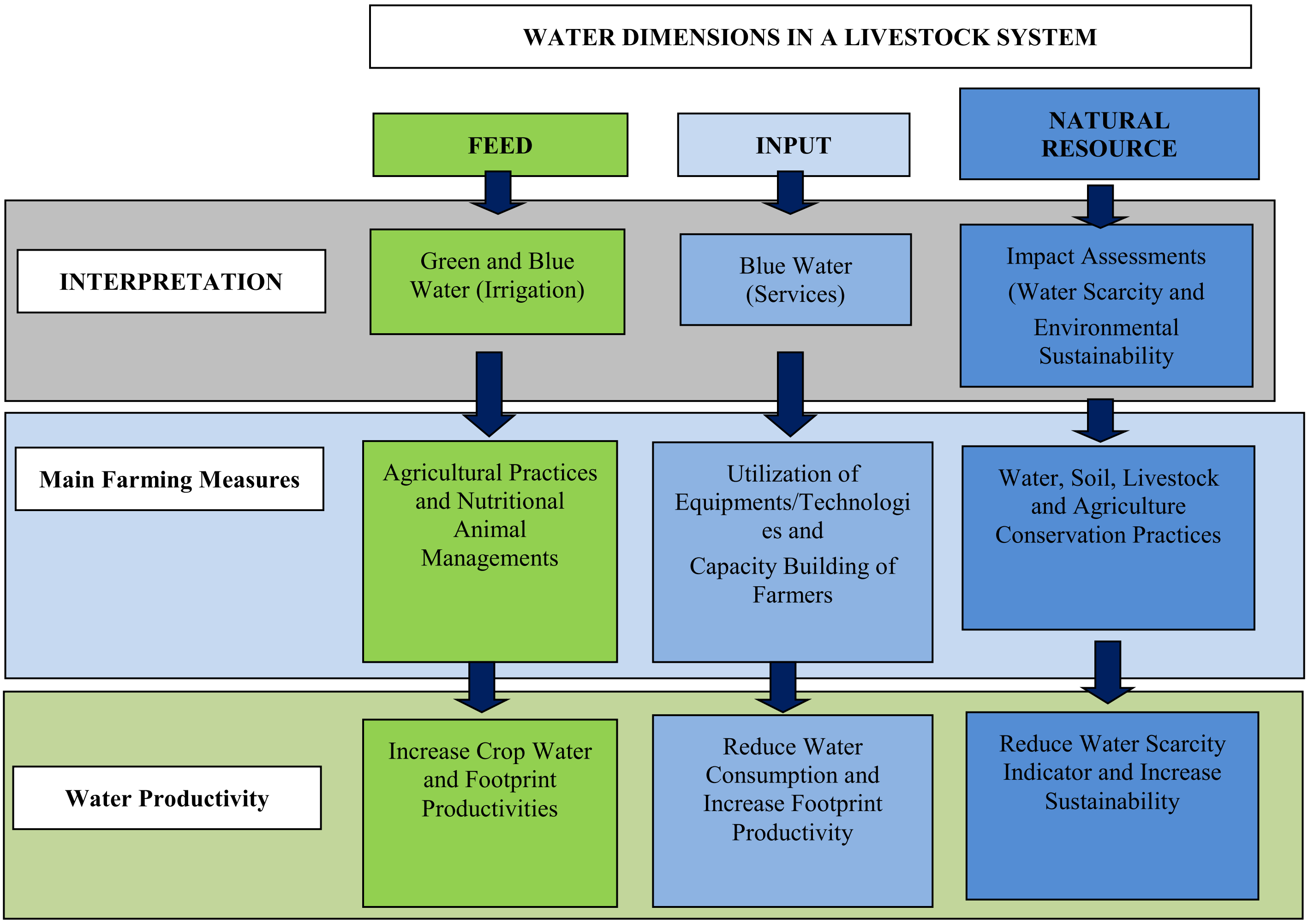

Figure 1. Water dimensions in a livestock system and their relation with water efficiency and productivity.

Figure 2. Farming measures and the environmental, social e economic impacts of increase water efficiency and productivity in livestock.

FARMING MEASURES

WATER

GREEN

Farming Measures

- Know all environmental legislation related to livestock and water and soil management;
- Utilize agricultural inputs considering all environmental, technical, and productive conditions;
- Consider meteorological information in the agricultural management;
- Analyze soil fertility according productive plant characteristics;
- Utilize soil conservation practices, including winter cover crops, and appropriate tillage practices;
- Feed composition should take water consumption by feed ingredients (evapotranspiration and/or irrigation) into consideration in order to formulate water-efficient diets;
- Precision feeding is formulating the ration to meet the nutritional requirements of the animals Diets must be properly formulated in order to avoid excessive water and feed intake and excretion of nutrients;
- Feed and dry matter intake shall be monitored;
- Maximizing the use of roughage feeds shall decrease the pressure on fresh water resources;
- Roughage-concentrate ratio and type of roughage are the nutritional aspects that most significantly influence the footprint values to ruminants;
- Use nutritional technologies such as amino acids, enzymes etc. to improve nutrients use efficiencies and animals performance;

Positive Impacts

ENVIRONMENTAL- conserve the soil, water, and the quality of downstream, increase the carbon fixation by the soil, reduce the emission of greenhouse gases, and preserve landscape, biodiversity and wildlife.

SOCIAL- dispose documents about environmental and water management, raise the level of information and knowledge about the importance of water, maintain a good relationship with neighbors.

ECONOMICAL- have an agriculture plan, increase the land production, reduce the cost with soil degradation

FARMING MEASURES	**WATER** **BLUE**	**Farming Measures**	**Positive Impacts**
		• Know all environmental legislation related to livestock and water resources; • Know the fluxes of water in the farm; • Installation of water meters; • Monitor the water quality consumed by the animals at least once a year; • Have actions and indicators to evaluate water consumption by animals and services (inputs); • Do not allow animals to consume water direct from rivers, streams, lakes and ponds; • Diets must be properly formulated in order to avoid excessive water and feed intake and excretion of nutrients; • Have an irrigation planning, consider measurements of soil moisture and climatic data to irrigate, utilize efficient irrigation equipments, and annually maintain the system; • Monitor the water system to maintain the cleanliness and elimination of leaks; • Always check if there is an occurrence of cracks, infiltration and leaks in water systems; • Follow the manufacturer's technical recommendations to use an equipment; • Distribute equipments and water drinkers in a correct way in the facilities and land; • Before removing wastes, scrape the installation floor; • Washing the facilities and equipments using water with pressure; • Walls and floors should be kept in good condition to avoid excessive use of wash water; • Use water and effluent reuse systems; • Document all interventions, actions, and management related to water consumption; • Have a capacity building program for the efficient use of water.	ENVIRONMENTAL- reduce the use of water, energy, and nutrients, produce indicators to evaluate the water productivity, give water security to the farm and to basin. SOCIAL- dispose documents about environmental and water management, facilitate the process to take the water and environmental licenses, reduce the conflict between production, basin community, and stakeholders, raise the level of information and knowledge about the importance of water, maintain a good relationship with neighbors and water agencies, assist policy makers to better understand animal-water-environment linkages so as to improve policy design and decision-making. ECONOMICAL- offer water in quantity to the husbandry, upgrade the feed management, have a water plan, improve the production and sanity in the farm, reduce the water cost.

Table 1. Water consumption for drinking and cleaning.

States	Pig slaughtered in 2008[1]	Consumption of drinking water (m^3)[2]	Consumption of cleaning water (m^3)[3]	Total (m^3)
Mato Grosso	1.059.594	370.858	3.603	374.461
Mato Grosso do Sul	836.919	292.922	2.846	295.767
Goias	1.544.191	540.467	5.250	545.717
Distrito Federal	152.556	53.395	519	53.913
Minas Gerais	3.123.386	1.093.185	10.620	1.103.805
Espirito Santo	155.969	54.589	530	55.119
Rio de Janeiro	4.530	1.586	15	1.601
Sao Paulo	1.535.187	537.315	5.220	542.535
Parana	4.618.377	1.616.432	15.702	1.632.134
Santa Catarina	8.420.777	2.947.272	28.631	2.975.903
Rio Grande do Sul	6.863.059	2.402.071	23.334	2.425.405

(1) (IBGE, 2009). (2) mean consumption 0,005 m^3 day^{-1}, growing-finishing period of 70 days with an mean weight of 93.3 kg (Palhares et al., 2009). (3) mean consumption 0.0034 m^3 of cleaning water (Palhares et al. 2009).

Table 2. Water footprint of pigs slaughtered in 2008 by State.

States	Corn Consumption (km^3)	Soybean Consumption (km^3)	Drinking and Cleaning Consumption (km^3)	Total (km^3)
Mato Grosso	0,210109	0,112071	0,000374	0,322554
Mato Grosso do Sul	0,114893	0,105492	0,000296	0,220681
Goias	0,227583	0,171106	0,000546	0,399234
Distrito Federal	0,019317	0,016110	0,000054	0,035481
Minas Gerais	0,555475	0,356297	0,001104	0,912877
Espirito Santo	0,053714	0,018185	0,000055	0,071954
Rio de Janeiro	0,001628	0,000528	0,000002	0,002158
Sao Paulo	0,252271	0,185696	0,000543	0,438510
Parana	0,573864	0,513627	0,001632	1,089122
Santa Catarina	1,293407	1,104965	0,002976	2,401348
Rio Grande do Sul	1,574055	1,125704	0,002425	2,702184

Table 3. Percentage of corn, soybean meal, and drinking and cleaning waters in the footprint.

States	Corn Consumption	Soybean Consumption	Drinking and Cleaning Consumption
Mato Grosso	65,1	34,7	0,12
Mato Grosso do Sul	52,1	47,8	0,13
Goias	57,0	42,9	0,14
Distrito Federal	54,4	45,4	0,15
Minas Gerais	60,8	39,0	0,12
Espirito Santo	74,7	25,3	0,08

Rio de Janeiro	75,4	24,5	0,07
Sao Paulo	57,5	42,3	0,12
Parana	52,7	47,2	0,15
Santa Catarina	53,9	46,0	0,12
Rio Grande do Sul	58,3	41,7	0,09

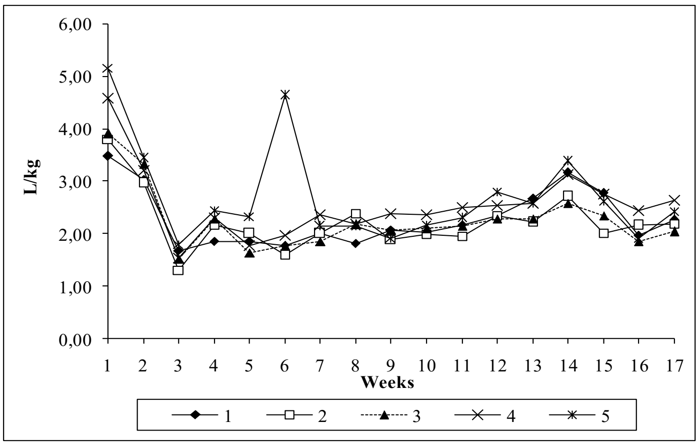

Figure 3- Relation between water consumption and waste production (L kg^{-1}).

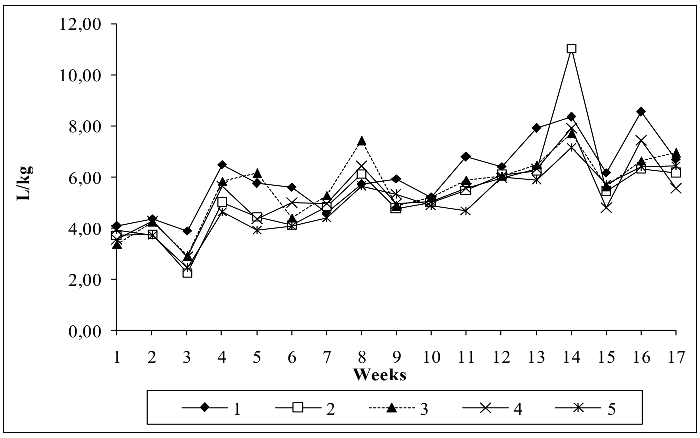

Figure 4- Relation between water consumption and weight gain (L kg^{-1}).

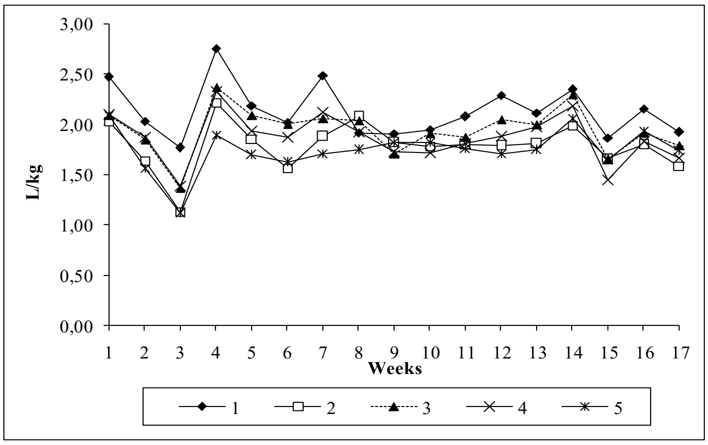

Figure 5. Relation between water consumption and feed consumption (L kg^{-1}).

Table 2. Water use efficiency (m^3 kg^{-1} of broiler slaughtered).

State	Year										
	2000	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
MG	2,2	2,2	1,9	1,9	1,8	1,8	2,1	1,8	1,9	1,7	1,7
ES	2,7	2,5	2,5	2,5	2,6	2,6	3,0	2,7	3,0	2,7	2,6
RJ	3,1	3,2	2,8	2,8	3,0	2,8	2,7	2,9	2,7	2,9	2,7
SP	2,3	1,9	1,8	1,7	1,8	2,0	1,8	1,7	1,7	1,8	1,6
PR	2,2	1,7	1,8	1,5	1,9	2,2	1,8	1,4	1,7	1,6	1,4
SC	2,0	1,7	1,9	1,6	1,9	2,2	2,0	1,5	1,8	1,7	1,5
RS	2,7	2,0	2,6	1,9	2,7	4,7	2,3	1,8	2,3	1,9	1,9
MS	2,4	1,7	2,1	1,6	2,3	3,7	1,9	1,6	1,9	-	-
MT	2,1	1,9	2,0	1,8	2,0	2,2	2,2	1,7	2,0	1,8	1,7
GO	1,8	1,7	1,7	1,6	1,8	1,8	1,8	1,6	1,7	1,6	1,5